DOCUMENT RESUME

ED 229 566 CE 035 818

TITLE	Heating and Ventilating II, 11-3. Military Curriculum Materials for Vocational and Technical Education.
INSTITUTION	Army Engineer School, Fort Belvoir, Va.; Ohio State Univ., Columbus. National Center for Research in Vocational Education.
SPONS AGENCY	Office of Education (DHEW), Washington, D.C.
PUB DATE	[78]
NOTE	129p.; For related documents, see CE 035 817-820.
PUB TYPE	Guides - Classroom Use - Materials (For Learner) (051)
EDRS PRICE	MF01/PC06 Plus Postage.
DESCRIPTORS	Autoinstructional Aids; Behavioral Objectives; Building Trades; Electrical Occupations; *Fuels; *Heating; Individualized Instruction; Learning Activities; Pacing; Postsecondary Education; Secondary Education; Textbooks; *Trade and Industrial Education; *Ventilation; Workbooks
IDENTIFIERS	Military Curriculum Project

ABSTRACT

This second course in a four-course series on heating and ventilating for the secondary/postsecondary level is one of a number of military-developed curriculum packages selected for adaptation to vocational instruction and curriculum development in a civilian setting. The five lessons in the course cover these topics: (1) Principles of Heating, (2) Fuel and Fuel Systems, (3) Heating Unit Installation, (4) Coal-Fired Furnaces and Stokers, and (5) Oil and Gas Burners and Controls. Designed for student self-study and evaluation, the course materials consist of a text and a student workbook. The text contains the reading assignments. Materials found in the workbook are lesson objectives, text assignments, lesson review exercises, answers to the exercises, and a discussion of those answers. A course examination is provided, but no answer key is included. The course may be used for remedial or independent study. (YLB)

****
* Reproductions supplied by EDRS are the best that can be made *
* from the original document. *
****

MILITARY CURRICULUM MATERIALS

The military-developed curriculum materials in this course package were selected by the National Center for Research in Vocational Education Military Curriculum Project for dissemination to the six regional Curriculum Coordination Centers and other instructional materials agencies. The purpose of disseminating these courses was to make curriculum materials developed by the military more accessible to vocational educators in the civilian setting.

The course materials were acquired, evaluated by project staff and practitioners in the field, and prepared for dissemination. Materials which were specific to the military were deleted, copyrighted materials were either omitted or approval for their use was obtained. These course packages contain curriculum resource materials which can be adapted to support vocational instruction and curriculum development.

The National Center Mission Statement

The National Center for Research in Vocational Education's mission is to increase the ability of diverse agencies, institutions, and organizations to solve educational problems relating to individual career planning, preparation, and progression. The National Center fulfills its mission by:

- Generating knowledge through research
- Developing educational programs and products
- Evaluating individual program needs and outcomes
- Installing educational programs and products
- Operating information systems and services
- Conducting leadership development and training programs

FOR FURTHER INFORMATION ABOUT
Military Curriculum Materials
WRITE OR CALL
Program Information Office
The National Center for Research in Vocational Education
The Ohio State University
1960 Kenny Road, Columbus, Ohio 43210
Telephone: 614/486-3655 or Toll Free 800/848-4815 within the continental U.S. (except Ohio)

THE NATIONAL CENTER
FOR RESEARCH IN VOCATIONAL EDUCATION
The Ohio State University • 1960 Kenny Road • Columbus, Ohio 43210
Tel: (614) 486-3655 Cable: CTVOCEDOSU/Columbus, Ohio

Military Curriculum Materials for Vocational and Technical Education

Information and Field Services Division

The National Center for Research in Vocational Education

Military Curriculum Materials Dissemination Is . . .

an activity to increase the accessibility of military-developed curriculum materials to vocational and technical educators.

This project, funded by the U.S. Office of Education, includes the identification and acquisition of curriculum materials in print form from the Coast Guard, Air Force, Army, Marine Corps and Navy.

Access to military curriculum materials is provided through a "Joint Memorandum of Understanding" between the U.S. Office of Education and the Department of Defense.

The acquired materials are reviewed by staff and subject matter specialists, and courses deemed applicable to vocational and technical education are selected for dissemination.

The National Center for Research in Vocational Education is the U.S. Office of Education's designated representative to acquire the materials and conduct the project activities.

Project Staff:

Wesley E. Budke, Ph.D., Director
National Center Clearinghouse

Shirley A. Chase, Ph.D.
Project Director

What Materials Are Available?

One hundred twenty courses on microfiche (thirteen in paper form) and descriptions of each have been provided to the vocational Curriculum Coordination Centers and other instructional materials agencies for dissemination.

Course materials include programmed instruction, curriculum outlines, instructor guides, student workbooks and technical manuals.

The 120 courses represent the following sixteen vocational subject areas:

- Agriculture
- Aviation
- Building & Construction Trades
- Clerical Occupations
- Communications
- Drafting
- Electronics
- Engine Mechanics
- Food Service
- Health
- Heating & Air Conditioning
- Machine Shop
- Management & Supervision
- Meteorology & Navigation
- Photography
- Public Service

The number of courses and the subject areas represented will expand as additional materials with application to vocational and technical education are identified and selected for dissemination.

How Can These Materials Be Obtained?

Contact the Curriculum Coordination Center in your region for information on obtaining materials (e.g., availability and cost). They will respond to your request directly or refer you to an instructional materials agency closer to you.

CURRICULUM COORDINATION CENTERS

EAST CENTRAL
Rebecca S. Douglass
Director
100 North First Street
Springfield, IL 62777
217/782-0759

MIDWEST
Robert Patton
Director
1515 West Sixth Ave.
Stillwater, OK 74704
405/377-2000

NORTHEAST
Joseph F. Kelly, Ph.D.
Director
225 West State Street
Trenton, NJ 08625
609/292-6562

NORTHWEST
William Daniels
Director
Building 17
Airdustrial Park
Olympia, WA 98504
206/753-0879

SOUTHEAST
James F. Shill, Ph.D.
Director
Mississippi State University
Drawer DX
Mississippi State, MS 39762
601/325-2510

WESTERN
Lawrence F. H. Zane, Ph.D.
Director
1776 University Ave.
Honolulu, HI 96822
808/948-7834

HEATING AND VENTILATING II

Table of Contents

Course Description Page 1

Fundamentals of Heating

Lesson 1 - Principles of Heating Page 6
Lesson 2 - Fuel and Fuel Systems Page 19
Lesson 3 - Heating Unit Installation Page 32
Lesson 4 - Coal-Fired Furnaces and Controls Page 47
Lesson 5 - Oil and Gas Burners and Controls Page 65
Workbook Page 88

HEATING AND VENTILATING II

Correspondence Course

11-3

Developed by:

United States Army

Development and Review Dates

Unknown

Occupational Area:

Heating and Air Conditioning

Cost:

Print Pages:

121

Availability:

Military Curriculum Project, The Center for Vocational Education, 1960 Kenny Rd., Columbus, OH 43210

Suggested Background:

Heating and Ventilating I (Course 11-2 in this catalog)

Target Audiences:

Grades 10-adult

Organization of Materials:

Student workbook containing objectives, assignments, review exercises, solutions to the exercises, discussion and examination; text

Type of Instruction:

Individualized, self-paced

Type of Materials:			No. of Pages:	Average Completion Time:
Heating and Ventilating II (Fundamentals of Heating)				
Lesson 1	–	Principles of Heating	14	Flexible
Lesson 2	–	Fuel and Fuel Systems	13	Flexible
Lesson 3	–	Heating Unit Installation	15	Flexible
Lesson 4	–	Coal-Fired Furnaces and Controls	18	Flexible
Lesson 5	–	Oil and Gas Burners and Controls	12	Flexible
Workbook			34	

Supplementary Materials Required:

None

Course Description

This is the second of four courses on heating and ventilating. The first course introduced the subject with a discussion of blueprints, tools, piping, electricity, and insulation. This course develops the subject further with instruction on the theory of heat transfer, combustion, fuels, and the operation, installation, and maintenance of space heaters, furnaces, boilers, stokers, and oil and gas burners. Five lessons on the following topics are included:

Lesson 1 – *Principles of Heating* discusses the theory of heat, measurement and heat transfer, combustion, primary and secondary air, perfect combustion, determining the volume of carbon dioxide, heat loss, the heat loss scale, and determining combustion efficiency.

Lesson 2 – *Fuel and Fuel Systems* contains information on solid fuels, liquid fuels, and gaseous fuels.

Lesson 3 – *Heating Unit Installation* covers the types, installation, operation, and maintenance of coal-fired, oil-fired, and gas-fired space heaters.

Lesson 4 – *Coal-Fired Furnaces and Stokers* discusses hand-fired coal furnaces, automatic stokers, and smokepipes and chimneys.

Lesson 5 – *Oil and Gas Burners and Controls* contains information on domestic oil burners, commercial oil burners, industrial oil burners, conversion oil burners, oil burner controls, gas pressure systems, types of gas burners, measuring gas pressure, maintenance of gas burners, burner feed assemblies, burner control systems, and conversion units.

The student workbook contains lesson objectives, text assignments, lesson review exercises, the answers to the exercises and a discussion of those answers. The text contains the reading assignments and appendices. A course examination is also provided, but no answers are available. The course was designed for student self-study and evaluation and can be used for independent remedial work or advanced study.

3

MEMORANDUM 565-1

HEATING AND VENTILATING II

(FUNDAMENTALS OF HEATING)

U. S. ARMY ENGINEER SCHOOL
FORT BELVOIR, VIRGINIA

11-3

MOS: 51J20

EDITION 1 (NRI 172)

PREFACE

THIS MEMORANDUM is written for personnel in the Army whose duties require them to have a knowledge of the fundamentals of heating.

The training, of which this second memorandum is a part, is intended for enlisted men who desire to progress in the MOS 51-J career field.

The discussions in the six chapters of this text are directed toward the principles of heating; fuels and fuel systems; and the construction, operation, installation, and maintenance of space heaters, furnaces and boilers, oil burners, and gas burners.

In the first chapter, there are discussions about the theory of heat, heat transfer, combustion, and heat loss. The second chapter covers solid, liquid, and gaseous fuels. The third chapter contains information regarding the types of coal-, oil-, and gas-fired space heaters. The third chapter also contains material concerned with the installation, operation, and maintenance of space heaters. The fourth chapter provides information about hand-fired and stoker-fired furnaces. This chapter also deals with types of furnaces, boilers, and stokers, and covers the construction, operation, installation, and maintenance of oil burners and burner controls, and conversion units. The material in the sixth chapter is centered on the construction, operation, installation, and maintenance of various types of gas burners and controls.

Keep this memorandum for your future use.

CONTENTS

Page

Preface i

Chapter

1 Principles of Heating 1

2 Fuels and Fuel Systems 14

3 Heating Unit Installation 27

4 Coal-Fired Furnaces and Stokers 42

5 Oil Burners and Controls 60

6 Gas Burners and Controls 72

CHAPTER 1

Principles of Heating

IT IS NOT KNOWN just exactly when man discovered fire, but there is no doubt that fire is one of the greatest gifts to mankind. The need to control and apply fire was apparent from the very first. Imagine what living conditions were during the cave-dwelling period. Unless a natural flue or some other method of ventilation existed as a result of the cave, the smoke from fires during cold weather must have created almost unbearable conditions, leaving the inhabitants the choice of either freezing or being asphyxiated.

2. Long after man had advanced to the stage of housebuilding, heating methods had not improved to a very great degree. For centuries (and occasionally, even today) fires for heating and lighting were contained in braziers or confined to an unused corner of a room. The smoke was supposed to escape through a hole left in the roof of the building during construction. Of course, considerable amounts of rain and snow entered the room during bad weather. During the twelfth century, however, the people in the northern part of Europe started using crude fireplaces and flues to replace the brazier and hole-in-the-roof method of heating. Some of these rudimentary heating systems still exist in France.

3. In the thirteenth and fourteenth centuries the round hollow stone chimneys began to be used. At the end of the fifteenth century, people were using a number of fireplaces in their homes and grouping the chimneys together in a vertical, rectangular mass of masonry with decorative effect. By the end of the Italian renaissance period, chimneys were in common use.

4. During colonial days in America, the fireplace chimneys were a large masonry mass projected through the center of the roof or were an important feature of the gable end walls. This general trend is often followed in architecture today. Central heating, where fires are required 5 or 6 months of the year, makes the chimney an important feature of a heating plant. There are heating installations, however, which do not make use of the masonry chimney and have substituted an inconspicuous metal smokepipe. Other types of heating, such as electrical heating, require no chimney.

5. Before discussing methods of heating, it seems logical to discuss the theory of heat, the measurement and transfer of heat, combustion, primary air, secondary air, perfect combustion, determining the volume of carbon dioxide, heat loss, heat loss scales, and determining combustion efficiency.

6. Knowledge of the theory of heat and heat measurement and transfer will be useful to you in understanding how heat is produced and how it gets from your heating plant to the space you are going to heat. Knowledge of combustion, primary air, secondary air, perfect combustion, determining the volume of carbon dioxide, heat loss, heat loss scales and determining combustion efficiency is very important information if you are to properly perform your job as a heating specialist. Also, this knowledge is a *must* if you intend to operate a heating plant efficiently.

7. Heat is one of the prime necessities of life. It is as essential as food, clothing, and shelter. You can have a very good shelter, but you still need heat to be comfortable in it. By studying this chapter, you will start to gain knowledge of just what you will be required to know to become efficient in your career field.

1. Theory of Heat

1-1. Heat is a form of energy that is known for its effect. Heat can be produced or generated by the combustion of fuels, by friction, by chemical action, and by the resistance offered to the flow of electricity in a circuit. However, the particular form of generated heat with which the heating specialist will be dealing is produced by combustion. This is heat obtained by burning common types of fuels such as coal, oil, and gas.

2. Measurement and Heat Transfer

2-1. To efficiently operate a heating plant, you must be familiar with the measurement of heat and how this heat is transferred from the plant to the space to be heated. The first part of this section is devoted to measuring temperature and pressure, whereas the second part deals with the transfer of heat from the plant to the space to be heated.

2-2. **Measurement of Heat.** Measurements of temperature and pressure, which are obtained continuously, are very important factors in the operation of a heating plant. The degree of correctness of these measurements directly affects the safety, efficiency, and reliability of operation of the heating plant. Although heat and temperature have a direct relationship, there is also a distinction between them. For example, a burning match develops a much higher temperature than a steam radiator, but the match does not give off enough heat to warm a room. Another example tells us that 10 pounds of water at 80° F. will melt more ice in a given length of time than 1 pound of water at 100° F. The former has more heat, but the latter has a higher temperature. Temperature is the measurement of heat intensity in degrees Fahrenheit or Celsius. Therefore, temperature measurements can be made by using a glass thermometer which is calibrated either in degrees Fahrenheit (F.) or degrees Celsius (C.). The generally accepted way of stating measurements of temperature is in degrees Fahrenheit. The Fahrenheit thermometer is the standard used primarily in English-speaking countries.

2-3. The thermometer measures the degree of sensible heat of different bodies. The thermometer can make a comparison only between the temperature of a body and some definitely known temperature such as the melting point of ice or the boiling point of water. Figure 1 shows a comparison of the scales of Fahrenheit and Celsius thermometers. It also shows the markings of the freezing and boiling points of pure water at sea level. The range of the Fahrenheit thermometer between the freezing point and the boiling point is 180° (32° to 212° = 180°). On the Celsius thermometer, the range is 100° (0° to 100° = 100°) from the freezing point to the boiling point.

2-4. To convert Fahrenheit readings to Celsius readings, it is necessary to subtract 32° from the Fahrenheit temperature reading and multiply the remainder by .556, or $\frac{5}{9}$. To change Celsius readings to Fahrenheit readings, multiply the Celsius temperature reading by 1.8, or $\frac{9}{5}$, and add 32°. The heat that can be measured by a thermometer and sensed or felt is referred to as *sensible heat.* An example of sensible heat is presented by placing a small vessel of cold water over a gas flame and putting a thermometer in the water. Upon observation, you note that the thermometer indicates a rise in temperature. Also, upon placing your finger in the water several times, you feel (or sense) the change in temperature that has taken place.

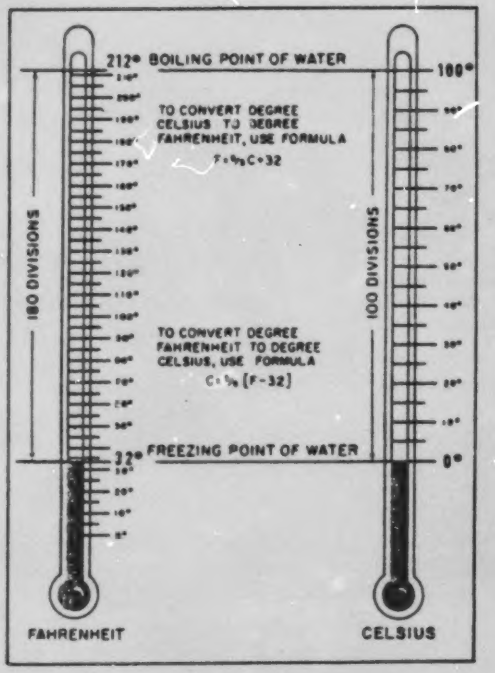

212° BOILING POINT OF WATER
100°
TO CONVERT DEGREE CELSIUS TO DEGREE FAHRENHEIT, USE FORMULA
F = 9/5 C + 32
180 DIVISIONS
100 DIVISIONS
TO CONVERT DEGREE FAHRENHEIT TO DEGREE CELSIUS, USE FORMULA
C = 5/9 (F − 32)
32° FREEZING POINT OF WATER
0°
FAHRENHEIT
CELSIUS

Figure 1. Comparison of Fahrenheit and Celsius thermometers.

2-5. The unit of measurement for a given quantity of heat is the British thermal unit, abbreviated and commonly known as Btu. One Btu is the amount of heat needed to change the temperature of 1 pound of pure water 1° Fahrenheit at sea level. If one Btu is added to 1 pound of water at 50° F., the temperature of that pound of water will be raised to 51° F.

2-6. All substances above absolute zero contain heat. There is heat even in ice, and its melting point is fixed at 32° F. Because of a fundamental law of nature, when ice at 32° F. melts into water at 32° F., a change of state takes place. It is that the ice (solid) has turned into water (liquid). A certain amount of heat is required during this change of state. This heat is known as the *latent heat of fusion.* When 1 pound of ice changes to water, 144 Btu are required, and an additional 180 Btu are required to further raise the temperature of the water to 212° F., the boiling point at sea level.

2-7. To again change the state of this 1 pound of water (once ice) at 212° F. to steam, another 970 Btu are required. This additional heat is known as the *latent heat of vaporization. Latent heat* is the amount of heat required to change the state of a substance without a measurable change in temperature. Heat indicates the quantity of units of heat (Btu) in a substance, while temperature indicates the intensity of heat in degrees.

2-8. There are other types of heat that you will encounter as a heating specialist. These are *specific heat, super heat,* and *total heat. Specific heat* is the ratio between the quantity of heat required to raise the temperature of one pound of any substance 1° F. and the amount of heat required to raise the temperature of 1 pound of pure water 1° F. *Super heat* is the amount of heat added to a substance above its boiling point. *Total heat* is *sensible heat* plus *latent heat.*

2-9. We previously mentioned *absolute zero.* But, what is *absolute zero?* Scientists have arbitrarily determined that when the temperature of a substance has been reduced to 460° below zero F. (–460° F.), practically all the heat has been removed from the substance. At this point the molecules cease to have motion. This temperature is known as *absolute zero,* and it is about the lowest temperature obtainable. Heat is said to be present in all substances when the temperature is above absolute zero.

2-10. **Heat Transfer.** The transfer of heat is the next problem to consider after the heat has been produced by burning a fuel. It must be moved to the space where it is to be used. Heat always flows from a warmer to a cooler substance; consequently, there must be a temperature difference before heat will flow. Naturally, the greater the difference in temperature is, the faster the heat flow. Two objects that have different temperatures, when placed together, will tend to equalize their temperatures. Heat travels in heating systems from one place to another by three different methods. All three of these methods are used in most heating systems; they discussed in the paragraphs that follow.

2-11. *Conduction.* Conduction is the flow of heat from one part of a substance to another part of the same substance, or from one substance to another when they are in direct contact.

2-12. When one end of a stove poker is held in a flame, the other end will soon be too hot to hold. This indicates that the heat is being conducted, or transferred, from one end of the poker to the other end. Such a transfer of heat is called *conduction.* Conduction is used to transfer heat through the walls of a stove, furnace, or radiator so that the warmth can be used for heating. If a piece of wood had been used, as an example, instead of the poker, the end of the wood away from the fire would have remained cool. This shows that some materials do not conduct heat as well as others. Those materials which offer considerable resistance to the flow of heat are referred to as insulators, or poor conductors. Some insulating materials were discussed in Chapter 5 of Memorandum 564.

2-13. *Convection.* Convection is the transfer of heat by means of mediums such as water, air, and steam. When air is heated, it expands, becomes lighter in weight, and rises. The cooler air, which is heavier, then flows in to replace the warm air. Thus, a convection current is set up. Water, when heated, acts in the same way as air. The water next to the heating surface becomes warmer, lighter, and rises. This action allows the cooler water to flow in next to the heating surface and become heated. Convection is a very important factor to be considered in a heating system. It is this force, developed by heating the medium, that circulates the heating medium to the space to be heated.

2-14. *Radiation.* Radiation is the transfer of heat through space. When a hand is held in front of a stove, it is quickly warmed by means of radiation. In this same manner, the earth receives its heat from the sun.

2-15. Radiated heat is transferred by heat waves, similar to radio waves. Heat waves do not warm the air through which they pass, but they must be absorbed by some substance to produce heat. For example, when you stand in the shade of a tree, you feel cool, because the leaves and limbs are absorbing the heat waves before they reach you.

2-16. When heat waves strike an object, some are reflected, some may pass through, and the rest are absorbed by the object. Polished metals are the best reflectors known; therefore, they are poor absorbers of heat. A poor absorber is also a good radiator. Rough metal absorbs heat more readily than a highly polished metal, and it also loses heat faster by radiation.

2-17. The color of a substance also affects its absorbing power. A black surface absorbs heat faster than a white one. That is why light-colored clothes are cooler in summer than dark-colored ones.

3. Combustion

3-1. Combustion is the rapid union of fuel, oxygen and heat. So, you will find that to produce and maintain a fire, fuel, air, and heat are necessary. You will also learn that the absence of any one of these ingredients will prevent burning or stop the fire. It is usually easy to understand that fuel is needed for burning, but it is sometimes difficult to understand that air and heat are also required.

3-2. To better understand the need of air for combustion, just recall that a burning match will stop burning soon after it is dropped into a bottle. This is because all the oxygen in the bottle is so quickly consumed by the flame.

3-3. We also said that heat is needed for combustion. This is because the temperature of the fuel has to be raised to its kindling point before it will start to burn. The kindling point of a substance is the temperature to which the substance must be heated for it to ignite. Every combustible substance has its own definite kindling point (ignition temperature). Substances such as paper and oil require only a small amount of heat before they will ignite. Others require a considerable amount of heat. When this temperature is reached, the substance begins to combine rapidly with oxygen in the air and soon creates a flame or fire which gives off heat. Light may also be given off.

3-4. Too much fuel, or not enough oxygen or heat, will produce incomplete combustion. The three ingredients (fuel, air, and heat) must be present in the correct amounts to provide complete combustion. When combustion takes place, the principal result is heat. Other byproducts such as carbon monoxide, carbon dioxide gases, and water vapor are also obtained.

3-5. Controlling combustion after a fire is built is an immediate problem. Air, fuel, and heat are necessary for combustion, and changing the amount of one or more of these will cause the fire to burn faster or slower. Two methods of controlling combustion are widely used. One method is to furnish a constant amount of air to the fire and vary the quantity of fuel. The other method is to furnish a constant quantity of fuel and vary the amount of air.

4. Primary and Secondary Air

4-1. To ignite a fire and have it continue to burn, it must have a continuous supply of air. In heating circles, this air is referred to as *primary air*. The primary air for coal-fired heating equipment is supplied by the draft door located below the grates, as illustrated in figure 2. Volatile combustible gases are formed above the fire as the fuel burns. More air is needed for these gases to burn properly, and it is supplied by slots in the feed door. This is called *secondary air*. The total amount of primary and secondary air required by a fire depends upon a number of factors. These include the type of fuel, depth of fuel bed, size of firepot, amounts of ashes and clinkers accumulated, and resistances offered by firebox passages.

4-2. Secondary air must be carefully controlled, because too much secondary air will cool the gases below the ignition point and be harmful instead of beneficial. Secondary air that enters the combustion chamber and is too far away from the combustion zone is useless, since the oxygen does not mix with the unburned gases. The air-fuel ratio of oil- or gas-burning heating equipment is generally very closely controlled. Methods of controlling this ratio are discussed later in this memorandum under gas and oil burners. In heating units where the air and fuel are controlled, combustion efficiency can be held at a maximum.

4-3. The smoke produced by a fire is a good indicator of combustion efficiency. When there is too much air, white smoke is produced; when there is too little air or too much fuel, black smoke is produced. The highest combustion efficiency is obtained when the proper amount of air is supplied with a minimum amount of smoke.

4-4. Certain gases are given off during the combustion process. Among these gases are two that are of importance to the fireman. They are carbon monoxide (CO) and carbon dioxide (CO_2). The percentage of these gases depends upon the amount of air (oxygen) mixed with the fuel. The proportion of air being used by a heating unit can be determined by checking the percentage of carbon dioxide in flue gas. This is why the carbon dioxide content of flue gas is considered

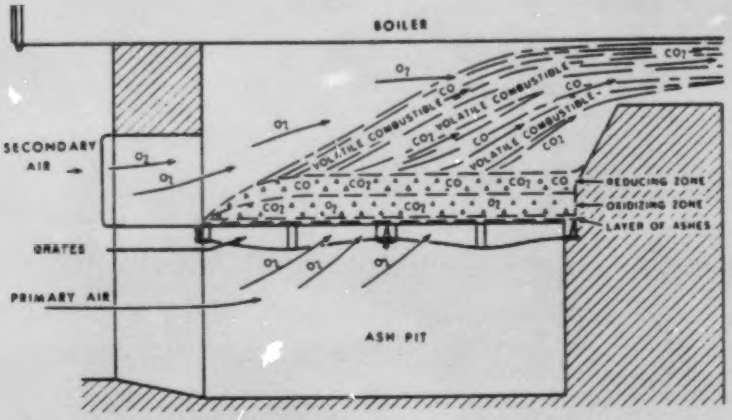


Figure 2. Combustion of coal

to be the most direct indication of combustion efficiency.

4-5. The most efficient combustion is attained by a fire that liberates the most heat from the fuel, uses the least amount of air, and produces the least amount of carbon monoxide.

4-6. In the burning process, two parts of oxygen unite with one part of carbon (fuel) to form carbon dioxide. So a definite amount of oxygen must be provided to burn a given amount of carbon. Any additional oxygen in the air will not enter into the combustion process and does not liberate additional heat. Unburned oxygen robs the furnace of usable heat and carries it out through the chimney. This is one of the big sources of waste in operating a heating plant. When combustion is complete, the resulting flue gas contains carbon monoxide and a trace of free oxygen. When combustion is incomplete, destructive carbon monoxide is present. Incomplete combustion is usually caused by the lack of oxygen during the burning process, or by the improper mixing of oxygen with combustible fuel. The percentage of carbon dioxide contained in flue gas is a direct indicator of the degree of perfection being attained in the combustion process.

5. Perfect Combustion

5-1. Perfect combustion would be the result of supplying the exact amount of oxygen required to oxidize, or completely consume, all of the combustibles, using every bit of oxygen. Perfect combustion is seldom, if ever, possible under practical conditions.

5-2. Perfect combustion would be attained only if it were possible to burn pure carbon and cause the resulting flue gas to contain 20 percent carbon dioxide. Conditions within a heating unit are neither perfect nor is the fuel ever pure carbon. There will always be less than 20 percent of carbon dioxide in the flue gas. The aim in practical firing is to secure the highest percentage of carbon dioxide attainable, without forming carbon monoxide—consideration being given to the kind and condition of the equipment involved, kind and quality of fuel, etc.

5-3. For a given set of conditions, there is a correct maximum carbon dioxide percentage that should be attained, either by hand firing or by automatic combustion control. This percentage depends on the type of fuel and the condition of the fuel-burning equipment used. You, the heating specialist, must know what this percentage is so that you can maintain the efficiency of your fire. If you are not getting maximum efficiency from your fire, you can make adjustments in the fuel and air supply to bring the efficiency to the desired point. If these adjustments do not bring the carbon dioxide content to the correct point, then the firing equipment should be checked. If all oxygen were to be consumed in burning the carbon (fuel), the resulting flue gas would contain approximately 20 percent carbon dioxide and 80 percent nitrogen. Because of the imperfect conditions existing within the average heating unit, however, excess amounts of air must be supplied to the fire so that all of the carbon will come in contact with sufficient oxygen to have combustion.

5-4. Most heating units are supplied with too much air in the effort to secure complete combustion. The excess air introduced into the combustion chamber dilutes the carbon dioxide. For example, if perfect combustion were attained by using the exact amount of air (oxygen) to burn a definite amount of fuel, the flue gas would contain about 20 percent carbon dioxide. However, if twice the exact amount of air were introduced into the combustion chamber, the flue gas would contain only about 10 percent carbon dioxide. Four times the amount of excess air would reduce the carbon dioxide content to about 5 percent.

5-5. It is the imperfect conditions existing within a heating unit that require excess air to be introduced in an attempt to attain efficient combustion. The amount of air to be admitted can be determined only by testing the flue gas for the percentage of carbon dioxide. Then, the object should be to produce the highest amount of carbon dioxide by using the smallest amount of air possible without producing carbon monoxide.

5-6. For burning coal, the best results are obtained with approximately 40 percent excess air, which produces about 15 percent carbon dioxide. Oil and gas burning require less air for good combustion than does coal. Under conditions similar to those for coal, when burning oil and gas with less than 40 percent excess air, the ultimate result is about 12 percent of carbon dioxide for oil and about 9 percent for gas.

5-7. Now that you have become acquainted with some of the problems you will encounter in obtaining combustion efficiency, you are ready to study the method used to determine the contents of combustion gases.

6. Determining Volume of Carbon Dioxide

6-1. The most reliable measurement of the percentage of carbon dioxide in flue gas is obtained by using a gas analyzer, or *orsat*. These gas analyzers are made by a number of manufacturers and are of various types; however, they all work on the same principle. A typical orsat is shown in figure 3. Basically, orsats analyze in this manner. A sample of flue gas is drawn into the analyzer through a tube inserted into the stack of the heating unit. The sample flows from the tube into the leveling bottle and through the filter, which takes out any suspended ash particles. Then the volume

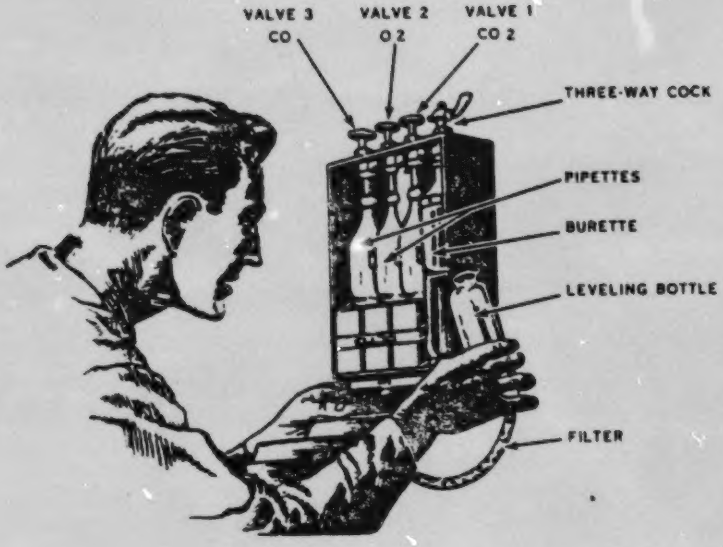


Figure 3. Measuring carbon dioxide with an orsat.

of the gas is measured. Your supervisor will furnish you with step-by-step instructions on the proper procedure for taking a flue gas test.

6-2. The flue gas is then passed through a chemical called *cardisorber,* which has an affinity for carbon dioxide. After this, the volume of flue gas is measured again. The difference in the volume before and after the absorption takes place gives the exact measurement of the carbon dioxide in the flue gas.

6-3. Most modern boiler rooms are equipped with permanently mounted types of carbon dioxide recorders that operate continuously. These recorders reveal the combustion conditions every 2 minutes. With a portable orsat, only a spot-check analysis can be made. You will note in figure 3 that there are three pipettes in the orsat; these are provided so that the three gases indicated in the figure can be measured. The purpose of the three-way cock is to clear the orsat after each of these gases has been measured, to keep from contaminating the next gas to be measured; thus assisting in insuring the accuracy of each test.

7. Heat Loss

7-1. The total heat loss from a heating unit can be divided into three groups. These groups are loss up the chimney; loss through the grates; and loss caused by conduction, convection, radiation, and so on. The heat loss up the chimney is by far the greatest thief. This heat loss can be further divided into other groups such as excess air loss, unburned fuel loss (smoke), and excess flue gas temperature. The heat losses by excess air loss and excess flue gas temperature loss are the greatest sources of up-the-chimney waste. Smoke, contrary to public conception, forms only a small percentage of the total heat loss, not over 2 to 3 percent.

7-2. Oxygen is used in the combination process, but nitrogen does not enter into the burning process at ordinary temperatures. For each cubic foot of oxygen that unites with carbon (fuel), 4 cubic feet of nitrogen enter the combustion chamber. Flue gas is usually heated to a temperature of about 500° Fahrenheit, and it is carried by the chimney to the atmosphere with the smoke. Consequently, much of the heat that should be absorbed by the boiler tubes or heat exchanger is wasted because of this excess air in the combustion chamber as a result of the amount of air being fed into the heating unit.

8. Heat Loss Scale

8-1. Figure 4 is a heat-loss scale which can be used to determine the efficiency of a fire when burning semibituminous coal. Suppose that the temperature of the flue gas in the stack is 550° Fahrenheit, and that the flue gas contains 10 percent carbon dioxide. According to the scale, the heat loss would be 20.7 percent.

8-2. One pound of fuel burning and producing only CO produces 4550 Btu. However, 1 pound of fuel burning and producing 20 percent CO_2 releases as much as 14,550 Btu. To decrease the heat loss and increase the percentage of carbon dioxide, you gradually reduce the air supply. Reduce the air supply to a point where an analysis will show just a trace of carbon monoxide. Sup-

SCALE OF HEAT LOSS IN FLUE GAS
(Stack Loss)
FUEL: Semi-bituminous Coal

% Loss With Stack Temperature 350°	% CO_2	% Loss With Stack Temperature 550°
9.2	18	13.5
9.4	17	14.0
9.7	16	14.6
10.1	15	15.3
10.6	14	16.1
11.2	13	17.0
11.8	12	18.0
12.5	11	19.2
13.3	10	20.7
14.4	9	22.6
15.7	8	24.8
17.4	7	27.7
19.7	6	31.5
22.9	5	36.9
27.6	4	45.1
35.3	3	58.5

Figure 4. Scale of heat loss.

ply just enough additional air to get rid of the carbon monoxide, and then allow the fire to burn in this manner without making any other adjustments. The carbon dioxide will increase, and the stack temperature will decrease considerably.

8-3. By cutting down the air supply, the carbon dioxide content would be raised to 14 percent and the stack temperature lowered to 350° Fahrenheit. Referring to the scale, the heat loss would reduce from 20.7 to 10.6 percent. This reduction in heat loss would amount to a saving of about 226 pounds of coal out of every ton.

8-4. The highest efficiency is attained when complete combustion is secured with a minimum of air supply. If perfect combustion could be attained, the resulting temperature would be high enough to melt the brickwork of the furnace and fuse the ash with the carbon and form slag on the grates. It is obvious that there are limits to the carbon dioxide percentages with which it is desirable to conform.

9. Determining Combustion Efficiency

9-1. Combustion efficiency can be determined from time to time when periodic checks are made. Graphs like those in figures 5, 6, 7, 8, 9, and 10 are used to determine the combustion efficiency when burning some of the common fuels.

9-2. To properly use these graphs, it is necessary to know four conditions. First, the percentage of carbon dioxide in the flue gas; second, the temperature of the flue gas; third, the room temperature; and fourth, the type of fuel being used. With this information at hand, you can determine the combustion efficiency. First, find the difference between the flue stack temperature and the room temperature. Next, locate the point that represents this difference on the bottom scale of the proper graph. Then find the diagonal line which represents the amount of carbon dioxide in the flue gas. Also find the point of interception of the two lines. Finally, draw a horizontal line to the left-hand scale from where the two lines intercept. The point at which the horizontal line crosses the left-hand scale represents the percentage of heating efficiency.

9-3. The figures given on these graphs are based on common fuel analysis. Better than average fuels will show a higher efficiency rating than those shown on the graphs; fuels below average will show a lower efficiency rating.

9-4. Suppose you are burning subbituminous coal in a heating unit; the flue gas temperature is 510° Fahrenheit; the room temperature is 80° Fahrenheit; and the flue gas contains 10 percent carbon dioxide. What is the combustion efficiency? Using the graph in figure 6, you find that the combustion efficiency is 78.5 percent. This means that 21.5 percent of the heat produced by the heating unit is lost through the stack.

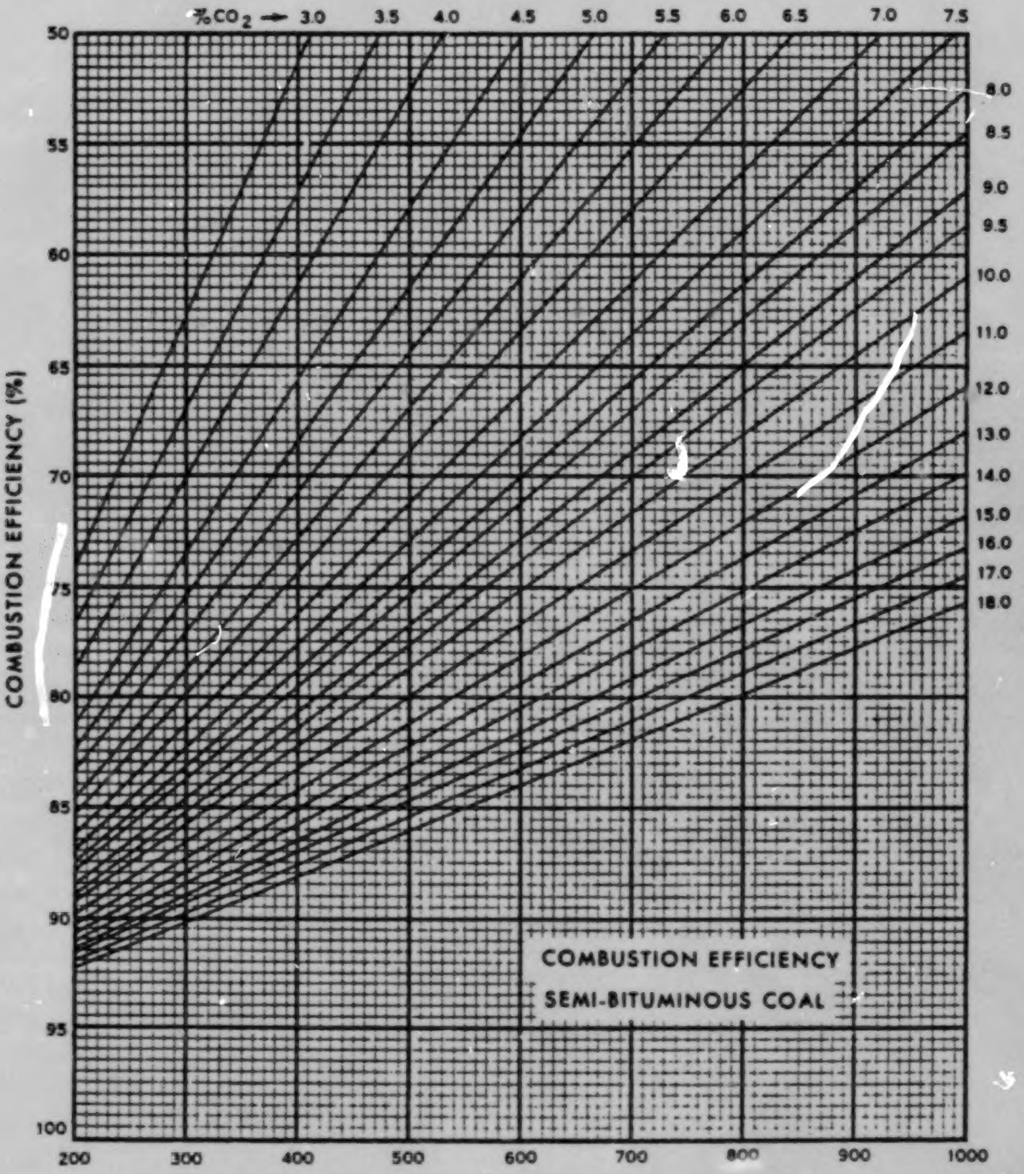

%CO2 →
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
COMBUSTION EFFICIENCY (%)
50
55
60
65
70
75
80
85
90
95
100
200
300
400
500
600
700
800
900
1000
COMBUSTION EFFICIENCY
SEMI-BITUMINOUS COAL

Figure 5.

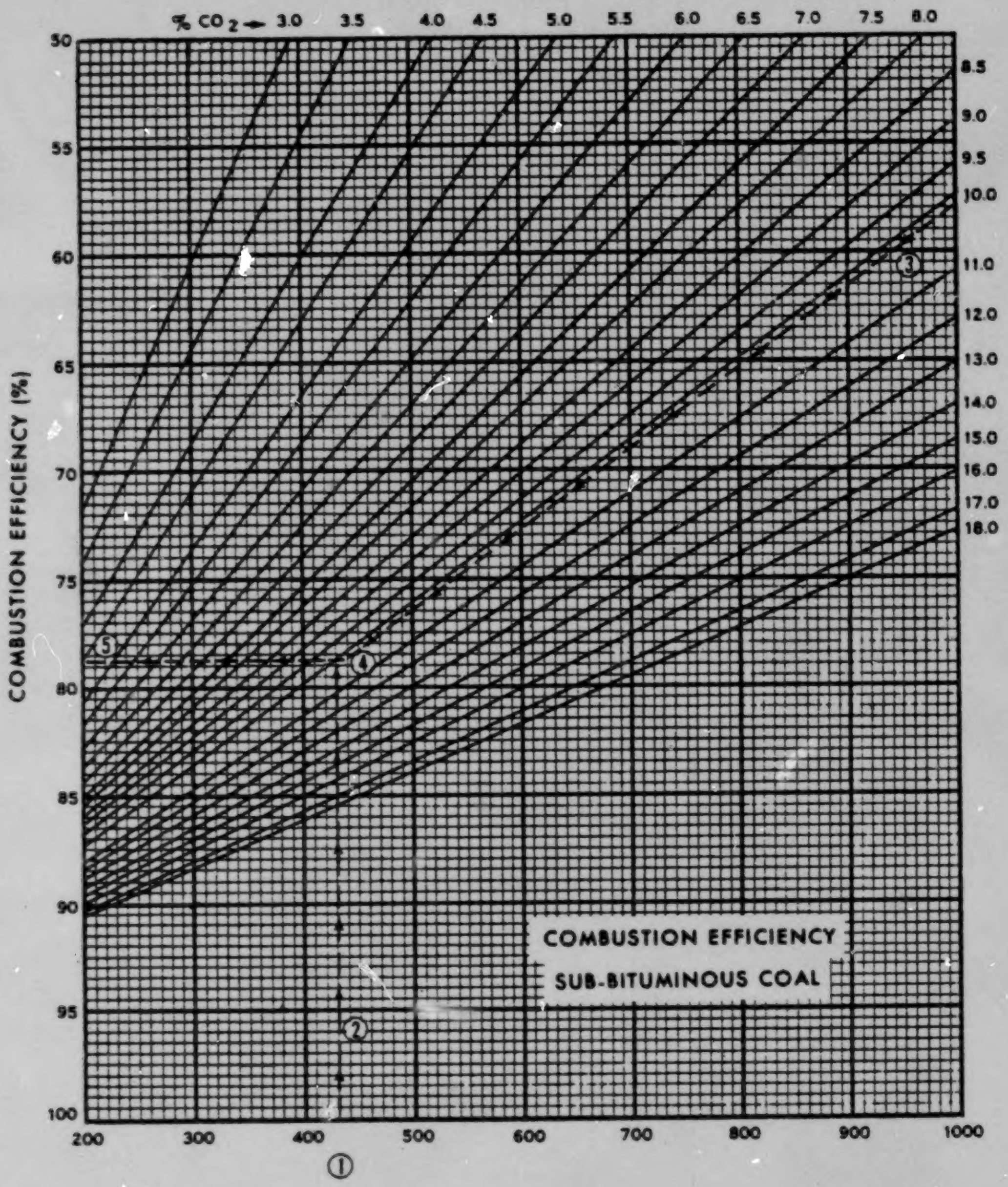

% CO2 →
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
18.0
COMBUSTION EFFICIENCY (%)
50
55
60
65
70
75
80
85
90
95
100
200
300
400
500
600
700
800
900
1000
①
②
③
④
⑤
COMBUSTION EFFICIENCY
SUB-BITUMINOUS COAL

Figure 6.

15

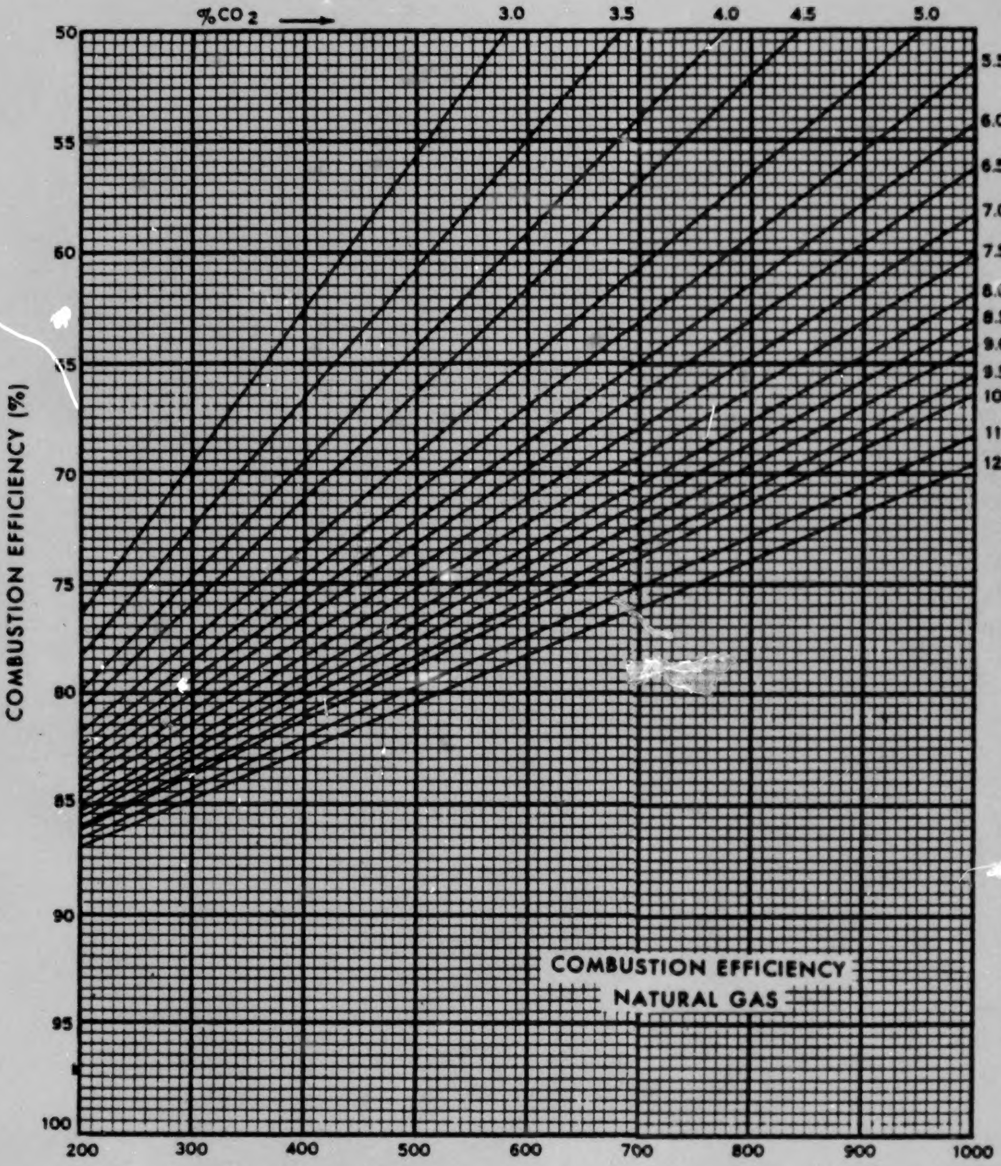


Figure 7.

23

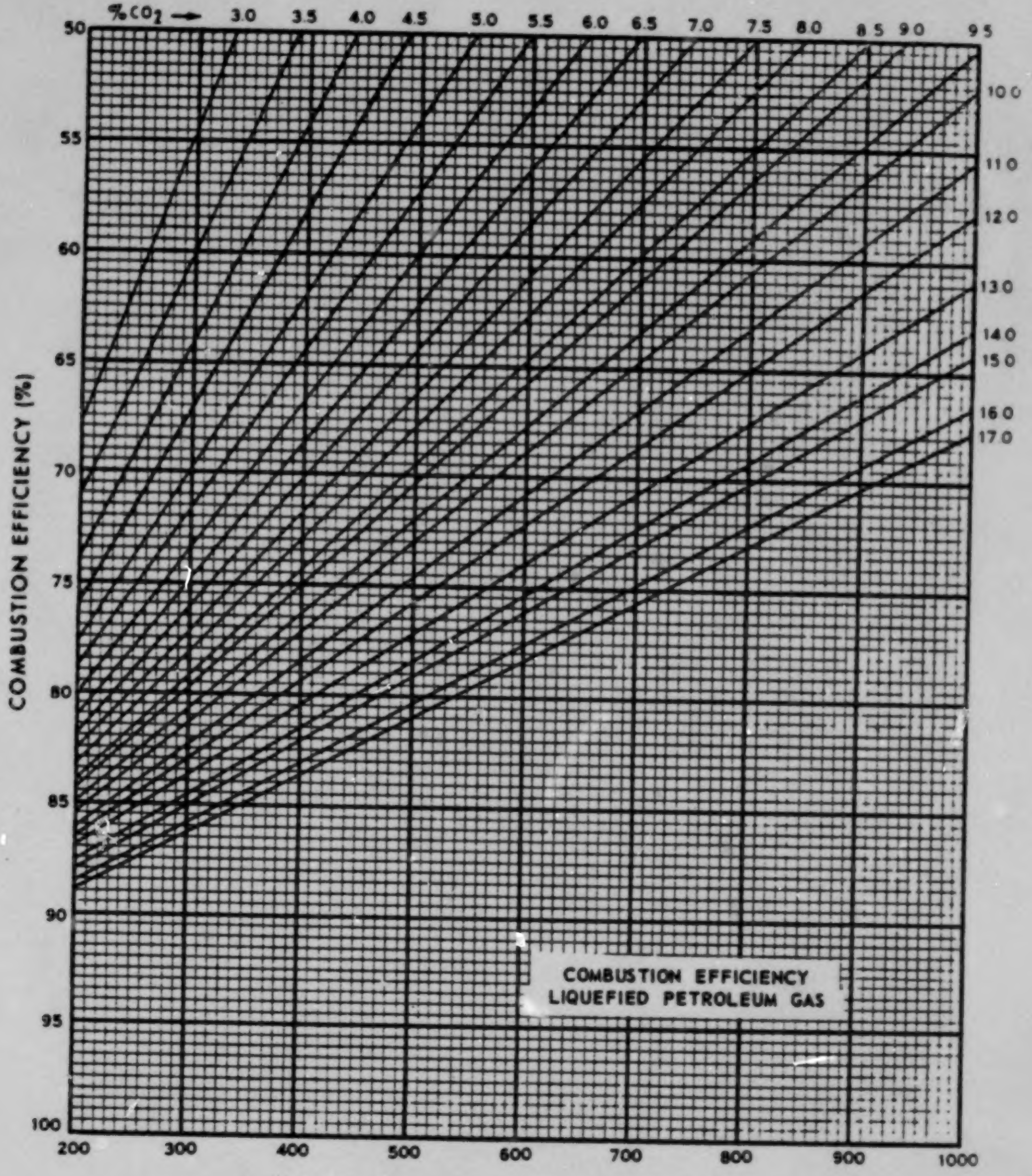

%CO2 →
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
11.0
12.0
13.0
14.0
15.0
16.0
17.0
COMBUSTION EFFICIENCY (%)
50
55
60
65
70
75
80
85
90
95
100
200
300
400
500
600
700
800
900
1000
COMBUSTION EFFICIENCY
LIQUEFIED PETROLEUM GAS

Figure 8.

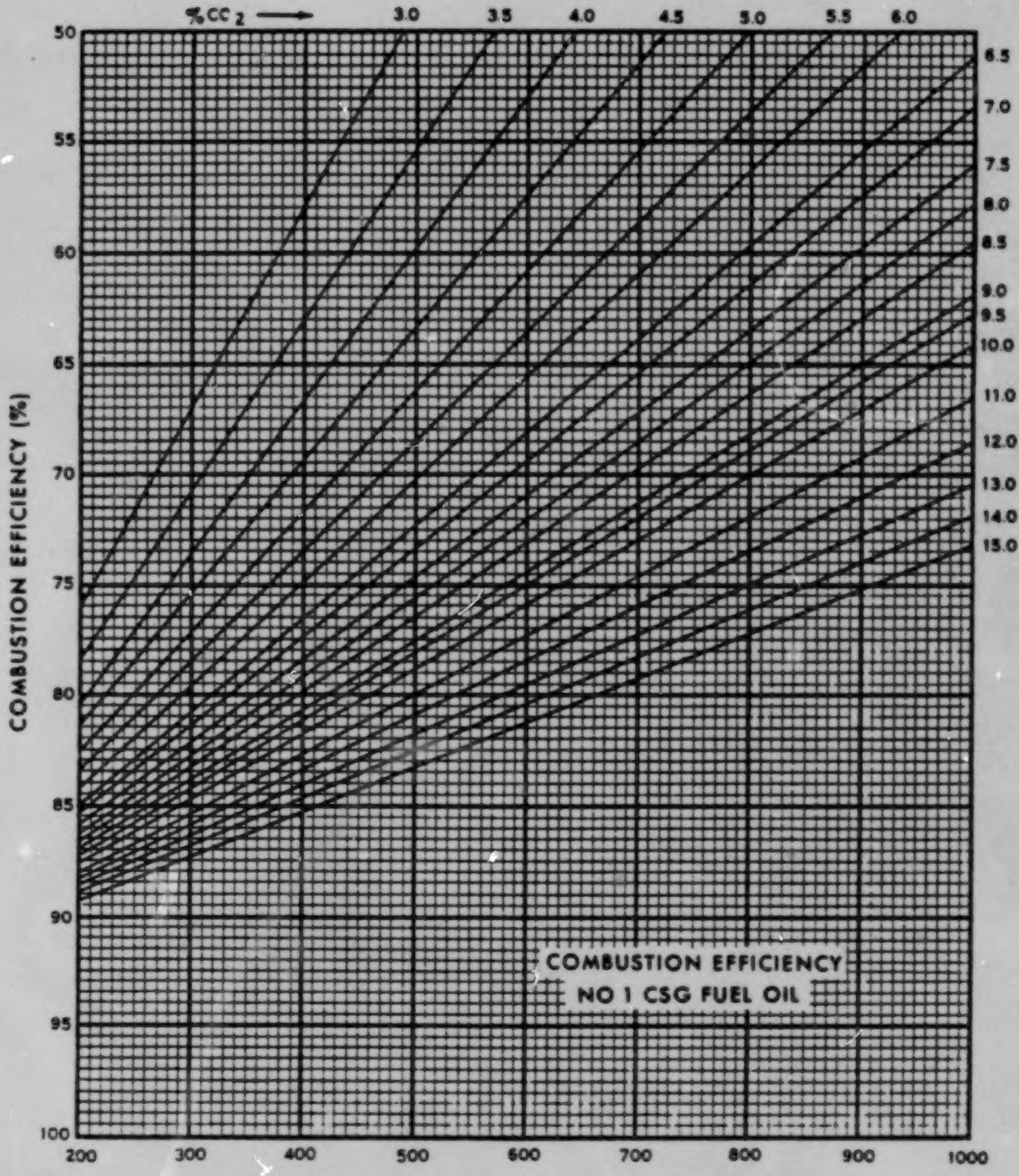

%CC 2 ⟶
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
11.0
12.0
13.0
14.0
15.0
COMBUSTION EFFICIENCY (%)
50
55
60
65
70
75
80
85
90
95
100
200
300
400
500
600
700
800
900
1000
COMBUSTION EFFICIENCY
NO 1 CSG FUEL OIL

Figure 9.

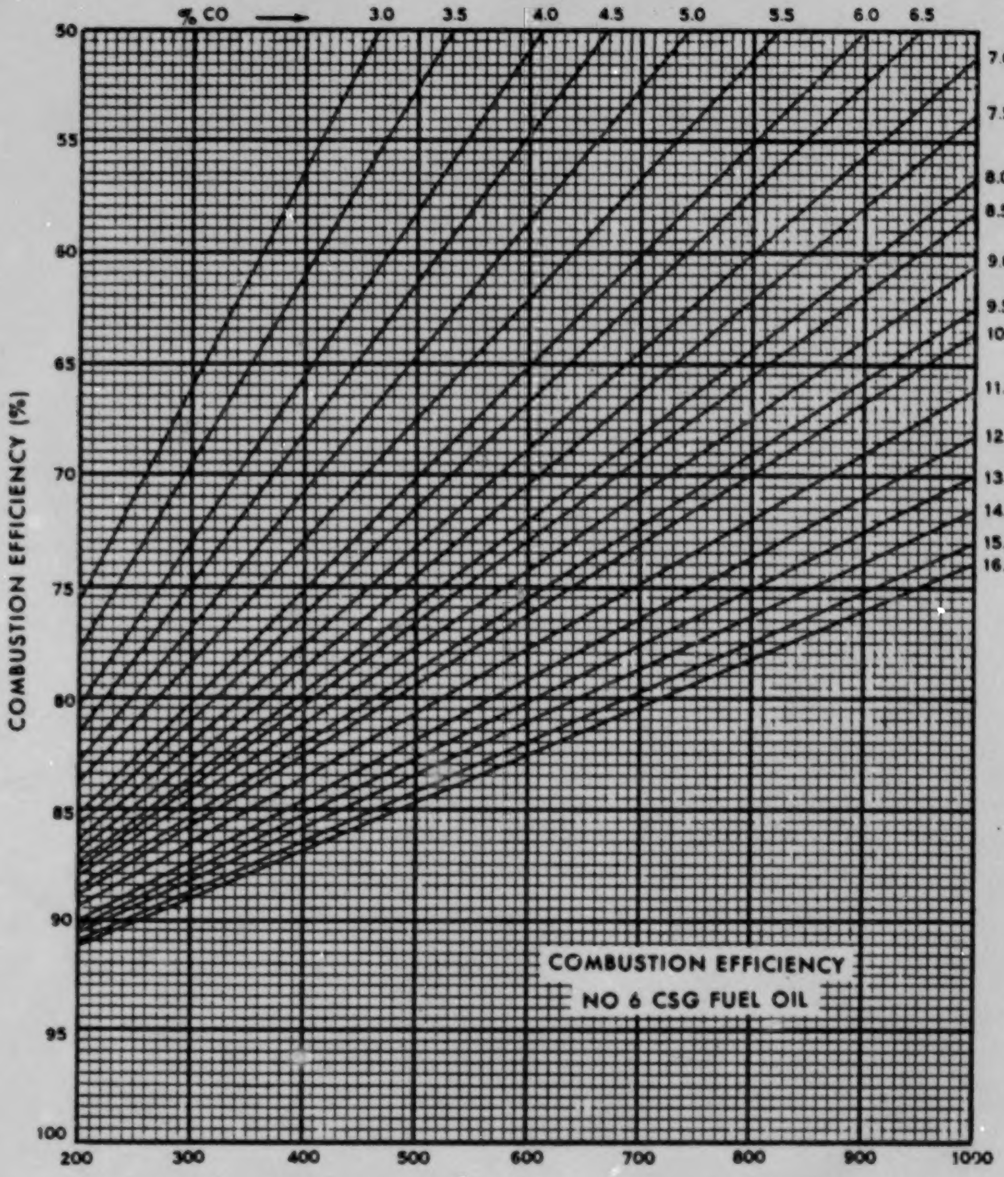

% CO →
3.0
3.5
4.0
4.5
5.0
5.5
6.0
6.5
7.0
7.5
8.0
8.5
9.0
9.5
10.0
11.0
12.0
13.0
14.0
15.0
16.0
COMBUSTION EFFICIENCY (%)
50
55
60
65
70
75
80
85
90
95
100
200
300
400
500
600
700
800
900
1000
COMBUSTION EFFICIENCY
NO 6 CSG FUEL OIL

Figure 10.

CHAPTER 2

Fuels and Fuel Systems

MANY TREES, ferns, and other types of vegetation have grown, died, decayed, and been covered with layers of the solid particles that form the earth's surface. This vegetation, which was held under great pressure for centuries, formed coal. Petroleum, from which fuel oil is derived, and natural gas are also of organic origin and are believed to have been formed by a similar process. Coal, petroleum, and gas are three major natural sources of fuel for heating systems. In order for you to efficiently do your job as a heating systems specialist, you must be acquainted with these fuels and must know something about their inspection, handling, storage, and characteristics.

2. In this chapter, you will read about various fuels and the fuel systems that burn them, and you will consider the characteristics of both. You will study the aspects of coal, coal inspection, coal sampling, coal storage, coal handling, and coal supply systems; oil, oil storage, oil supply systems, and units of the fuel oil systems; and natural gas, liquefied petroleum gas, blast furnace gas, and gas supply systems.

10. Solid Fuels

10-1. Millions of tons of coal are purchased annually by the military. All contracts for coal procured for the Air Force are handled by the Department of the Navy. Virtually all contracts are awarded on the basis of a Bureau of Mines analysis requiring careful periodic sampling and analysis.

10-2. To have a better understanding of the properties of coal, it is necessary for you to know its composition. Coal is a mineral formed in the earth by decayed plants, trees, and other forms of vegetation. Chemically, it is composed of varying proportions of carbon, hydrogen, oxygen, sulphur, and noncombustible materials called ash. The several different kinds of coal purchased by the military are anthracite, bituminous, subbituminous, and lignite.

10-3. Anthracite is the hardest grade of coal obtained. It is very dense and stonelike in structure and has been referred to as stone coal. In its natural formation there are no faces, butts, or natural lines of cleavage. It must be crushed or reduced in size for the market by breakers specially designed for this purpose. Anthracite has a very shiny, black appearance as compared with other grades of coal, and it is minutely sized. Variations in smaller sizes are measured in sixteenths of an inch, and variations in larger sizes are measured in quarter and half inches. Because of its hard structure, anthracite does not degrade or break easily during handling and storage. It is low in moisture and volatile content, but high in fixed carbon.

10-4. Bituminous coal is commonly referred to as soft coal. It is the type of coal most used by the military. Bituminous coals have a wide variety of physical and chemical properties. They are semidense, not granular, and are blocky in structure. Because of the natural faces, butts, and lines of cleavage, the prepared sizes are cubical in shape and retain this shape after breakage. Degrees of hardness vary; some bituminous coals are quite firm in structure and present no particular handling problems to prevent size degradation. Others coals, because of natural slips or independent faces, undergo considerable size degradation with normal handling.

10-5. Subbituminous is the next to lowest in rank of coal used by the military. Only about 2 percent of all coal used by the military is subbituminous. However, as much as 70 percent of the total requirements used at one installation may be of this type. Subbituminous coal is mined and consumed in western sections of the United States. Freshly mined subbituminous coal closely resembles ordinary bituminous coal in density, structure, and fracture, but its appearance is slightly duller. Chemically, it is distinguished from bituminous coal by its high moisture content, which ranges from 20 to 30 percent. The average ash content of subbituminous is approximately 4 percent lower than the average ash content of ordinary bituminous. Also, the average British thermal unit (Btu) content is approximately 2,500 less per pound wet and approximately 1,000 less per pound dry than bituminous. The average ash softening temperature is approximately 400° F. higher than that of average bituminous.

10-6. Lignite has the same general characteristics as subbituminous coal, but it has a higher moisture content and a lower Btu value. Lignite is used only at installations where it is consumed immediately after being mined.

10-7. **Coal Inspection.** Coal inspection insures that the coal supplier complies with the coal contract specifications. It includes a visual inspection and a chemical analysis.

10-8. A visual inspection is made to see if the shipment is made in the type of car specified in the contract. As stipulated on DD Form 416, first and second preference must be stated in the space provided. If coal is shipped in an unauthorized type of railroad car, it should be accepted only under protest, through the appropriate military command to the purchasing agent.

10-9. When inspecting coal to determine that it is reasonably free from impurities, the inspector must rely on his knowledge of the appearance of previous shipments. The relative condition of any carload must be established by comparison with the average condition of previous carload shipments from the same source. When visually inspecting a carload or truckload of coal, the entire top of the car is examined closely. It is inspected at nine or more points in three diagonal lines across the top of [illegible] car. Dig into the coal and expose it to a minimum depth of 2 feet.

10-10. Coal should be checked for freedom from slate, boney coal, sulphur balls, rocks, dirt, mud, clay, and other impurities. Coal that is stained or colored yellow, red, orange, or chalky gray is generally outcrop coal or coal with cover so shallow that surface water seeps into the stratum of coal and stains it, not only on top but on slips and butts. A stratum is a sheetlike mass of sedimentary rock or earth of one kind, usually in a layer between beds of other kinds. Ordinarily, outcrop coal is of poor quality, high in ash, low in heat units, and soft and friable (easily crumbled).

10-11. The loss or theft of coal in shipment should not exceed 1 percent of the weight of coal as it is shown on the shipping bill of lading. The loss of coal can be detected by the disturbed or irregular appearance of the coal at the top of the car. If the contents of the car appear to have been disturbed, a record of this is made.

10-12. Coal should be rejected when the results of the visual inspections are unsatisfactory. In this case, the post engineering office of the appropriate Army command concerned should be notified immediately and the authority obtained for rejection.

10-13. **Coal Sampling.** Sampling is one of the most important features of determining the successful and satisfactory application of the specification method of purchasing coal. Its purpose is (1) to furnish the means whereby the Government is assured of receiving the coal contracted for; (2) to protect the interest of the Government by providing the means for determining liquidated damages if contractors fail to deliver coal of the quality guaranteed; and (3) to furnish the purchasing officer an official basis for making his purchases. The importance of proper sampling and analyzing in the Government coal purchases is therefore obvious.

10-14. Every sample must be collected and prepared carefully and conscientiously. The sampling is of primary importance. If the sample is improperly collected and prepared, it is usually impossible or impracticable to collect another; whereas if an analysis is in error, the reserve portion can be analyzed.

10-15. Samples must be collected by a trained and experienced sampler. Officials responsible for the sampling must witness the process from time to time to insure proper collection and preparation of the samples. A sampler may be required to certify the method of collecting and preparing samples. The purpose of certification is to stress the importance of doing the sampling conscientiously and to fix the responsibility for proper sampling.

10-16. The time to take the sample of coal is while the coal is in motion, that is, during the loading or unloading. When this is not possible, top sampling can be employed. When it is necessary to take samples from the top, it shall be stated in the report that top sampling was employed. Samples should not be collected from the tops or sides of piles in storage areas, because samples so collected are unreliable and are not representative of the car or truck of coal.

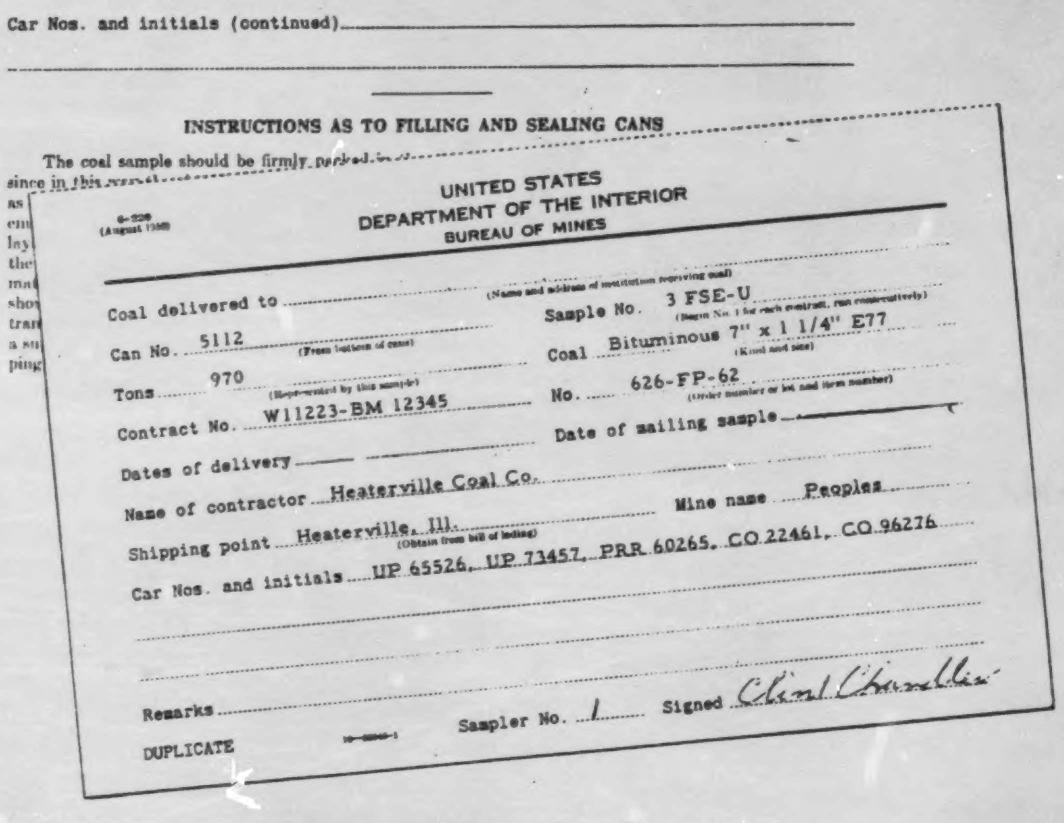
10-17. A gross coal sample, totaling not less than 1000 pounds of coal, should be gathered in proportionate amounts from the total cars of coal to be examined. The gross sample must not represent more than 20 cars or 1000 tons, or include coal from mines other than that which is included in the contract. The weight of coal taken from individual cars to make a gross sample varies with the number of cars. For instance, if one car is sampled, then 1000 pounds should be taken from that car. However, if 20 cars are sampled, then 50 pounds should be taken from each car. The same procedure is used when taking samples from dump trucks, except that with dump trucks, the samples can be taken from more than 20 truckloads provided the total tonnage does not exceed 1000 tons.

10-18. When taking samples from hopper-bottom cars and dump trucks, the very first or the last coal running should never be used. The best method to use in collecting samples is to pass a shovel through the stream of coal as it is flowing. Extreme care should be taken when passing the shovel through it, because the coal is traveling at a fast rate of speed.

10-19. As the samples that make up the gross sample are collected, they are deposited in a suitable receptacle, such as a wooden bin or metal can equipped with a tightly fitting lid, until the gross sample is completed. All receptacles must be kept as nearly airtight as possible. This is to eliminate deterioration or contamination by foreign matter. A card or paper with an identification record should be attached to each receptacle. This record should show the coal sample number, contract number, name of the originating railroad, kind and size of coal, initial and number of each car from which a sample was drawn, date the coal sample was drawn and placed in the receptacle, and approximate weight of the original coal sample.

10-20. A gross coal sample is prepared by crushing the coal from its original size to particles which will pass through a $\frac{3}{16}$-inch screen. If a crusher is not available, the crushing can be done with a suitable tamper or sledge. If a mechanical crusher is used, and if it has a splitter, the crushed coal is run through the splitter until there are about 65 pounds of crushed coal left. This will be enough to fill a standard Bureau of Mines riffle bucket. Next, the 65-pound sample is hand-riffled down to about 3 pounds, or enough to fill the standard Bureau of Mines coal-sampling shipping container.

10-21. All entries regarding the coal sample are made on the United States Department of the Interior, Bureau of Mines, Form 6-220. This form, properly filled out, is shown in figure 11. It can be procured from the Bureau of Mines, Pittsburgh, Pennsylvania. The form is completed in duplicate. The original is sent with the coal sample to the Bureau of Mines. The duplicate is kept on file. In case you are interested in the instructions on preparing the Bureau of Mines Form 6-220, refer to the United States Bureau of Mines, Technical Paper 133,



Car Nos. and initials (continued)

INSTRUCTIONS AS TO FILLING AND SEALING CANS

The coal sample should be firmly packed in
since in this vessel
as
em
lay
the
ma
sho
tran
a su
ping

6-220
(August [illegible])

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF MINES

Coal delivered to (Name and address of institution receiving coal)
Sample No. 3 FSE-U (Begin No. 1 for each contract, run consecutively)
Can No. 5112 (From bottom of case)
Coal Bituminous 7" x 1 1/4" E77 (Kind and size)
Tons 970 (Represented by this sample)
No. 626-FP-62 (Order number or lot and item number)
Contract No. W11223-BM 12345
Date of mailing sample
Dates of delivery
Name of contractor Heaterville Coal Co.
Mine name Peoples
Shipping point Heaterville, Ill. (Obtain from bill of lading)
Car Nos. and initials UP 65526, UP 73457, PRR 60265, CO 22461, CO 96276
Remarks
Sampler No. 1
Signed Clint Chandler
DUPLICATE

Figure 11. Bureau of Mines Form 6-220.

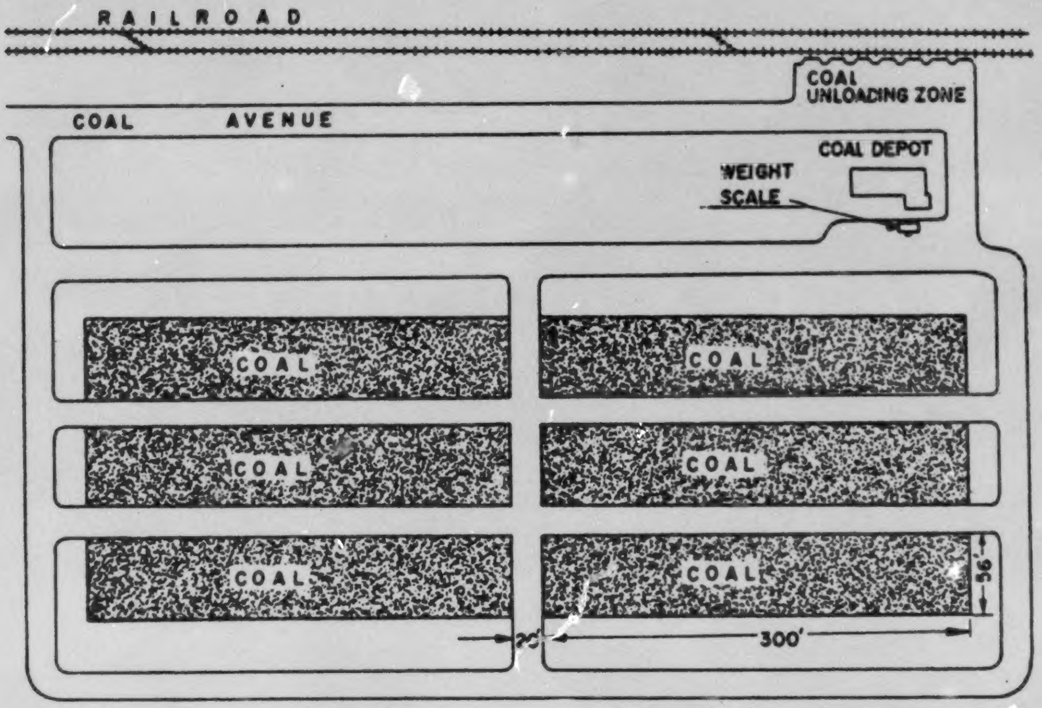


Figure 12. Typical coal storage layout.

dated 1957. The above references also pertain to the preparing and mailing of coal samples.

10-22. **Coal Storage and Handling Equipment.** Coal should be stored only on ground which has been properly graded and surfaced. A typical coal storage layout is shown in figure 12. The improper storage of coal can cause spontaneous combustion. Usually, some of the coal is wasted when it is stored on soft ground, because it sinks into the ground and mixes with the dirt and other foreign matter. When this situation occurs, the foreign particles in the coal usually warp the grates of heating units, the replacement of which results in the loss of manpower. There is also extra wear and tear upon the equipment used to move such noncombustible materials. Heavy coal losses usually occur when the coal is stored without proper drainage. The paragraphs that follow contain some of the rules which should be followed to minimize the loss of coal during storage.

10-23. Coal should never be stored near sources of heat, and fresh coal should not be piled over old coal. The storage piles and storage surfaces should be kept free of metal scrap, rags, paper, waste, scrap wood, glass bottles, and other foreign materials.

10-24. Some sizes of bituminous coal, including lump, egg, and nut, are not piled higher than **18 feet, to prevent spontaneous combustion, except with the specific approval of the Army command concerned. Storage of bituminous, run-of-mine coal should be limited to a maximum height of 13 feet, unless higher stock piling is approved by the Army command concerned. Anthracite coal may be stored to any desired height within economic limits.**

10-25. Different sizes and kinds of coal should be stored in separate piles according to grade, size, and function. There are, however, a few exceptions. Anthracite coals of the same size, regardless of origin, should be stored in the same pile. Bituminous coal of the same size, mined from the same vein or of the same characteristics, should be stored in the same pile. Bituminous lump coal with top size variation not to exceed 5 inches and bituminous egg with top size variation not exceeding 3 inches should be stored in the same pile, if they have the same characteristics.

10-26. Coal is generally stored in stock piles 300 feet long and 56 feet wide. An allowance of 20 feet should be made between the stock piles for firebreaks. The firebreaks also serve as driveways and loading zones. This arrangement permits efficient truck loading and travel, ample room to operate coal handling equipment, and sufficient room to spread or shift the coal in case a fire starts in one of the stock piles. The shifting and rehandling of coal in stock piles should be held to a minimum to prevent the breakage and disintegration of coal into smaller pieces.

10-27. The discharge end of a conveyer stacker should be kept as close as possible to the top of the stock pile or truck bed to avoid breaking the coal by dropping it too far. When the maximum height of the stacker is reached, it should be moved a sufficient distance to discharge the coal on the side and near the top of the stock pile. The distance of the move should not exceed 6 feet.

10-28. Good judgment should be used when storing coal with a clamshell crane. Care should be taken to keep coal breakage at a minimum. Fines or slack coal creates a fire hazard in the coal storage pile.

10-29. It is sometimes necessary to shift storage stock piles at posts where a large tonnage of coal is stored. If this work is done with a clamshell crane, the shift can be made with very little damage to the coal, providing the coal is not discharged from the bucket until the bucket is lowered close to the pile so that only enough room is allowed to open it. The position of the crane is also arranged to reduce the angle of swing, thus saving time and increasing the daily tonnage moved. Storage stock piles of sized coal should never be shifted by pushing them with a bulldozer.

10-30. Coal should be stored in uniform stock piles. The sawtooth piling that causes marked variations in the height of a stock pile should not be permitted. To avoid sawtooth piling, the conveyer stacker or clamshell must be moved only short distances. These short moves make it possible to run a stock pile of uniform height, provide a natural side slope on the pile, reduce the breakage of coal, eliminate lowering and raising the conveyer stacker, and save storage space. Coal stored in irregular piles is very difficult to inventory.

10-31. Storage piles should be inspected at least once a week for evidence of excessive heating or spontaneous combustion. Such evidence is ordinarily discovered by evidence of steam, or by the odor of coal gases escaping from the coal piles. To make a complete inspection of the coal piles, ¾-inch metal pipes, closed at the bottom and reaching nearly to the base of the coal, are placed in the coal pile approximately every 25 feet. With this arrangement, thermometers can be lowered into the pipes for checking the temperature of the coal pile at that point. The pipe should not be removed once it has been inserted, because the hole left in the pile by the pipe aids in the generation of heat. If the temperature of the coal reaches 120° F., the coal should be watched closely for any rapid rise in temperature and provision made for immediate removal of the hotspot when the rise occurs. If the temperature rises to about 160° F., within a week, there is danger of spontaneous ignition and you should remove the hotspot immediately.

10-32. Metal rods, having diameters from ¼ to ½ inch, can be used instead of the metal pipes and thermometers to detect heat in piles of coal. The rods are pushed down into the coal nearly to the base of the piles approximately every 25 feet. They are withdrawn after they reach a constant temperature, which requires about 2 hours. If the inserted portion of the rod can be held in the hand at the hottest point, there is little danger of immediate ignition. However, if the rod is too hot to hold in your hand, you should remove the hotspot of coal immediately.

10-33. Water should not be applied to burning storage coal piles to extinguish a fire, or to storage coal piles which are heating. Water has a tendency to aggravate both conditions, and spreads the fire or hotspots to other points in the storage pile. Water should be applied to hot or burning coal only after it has been removed from the stock pile. Hot or burning coal should be removed from a stock pile preferably with clamshell cranes, power shovels, or all-metal conveyers. Removing hot or burning coal by hand with a shovel is slow and dangerous. All coal in the vicinity of the fire which has a temperature of 100° F. or more should be removed. Any coal which has been damaged by heat or fire should be aerated and used at once. If the entire stock pile or a large portion of it shows danger of heating, the entire pile or affected portion should be removed, aerated, and restored. Slack coal or screenings should be thoroughly compacted after the temperature has dropped to a safe point.

10-34. **Coal Supply Systems.** Coal is usually transferred from the storage pile to a bin or area near the heating system where it is to be used. From there, the coal is placed in the combustion chamber of the heating unit either by hand or by mechanical means. The coal for domestic installations, if mechanical means are used, is placed in the combustion chamber by means of a small screw-type conveyer tube, such as that shown in figure 13. This feed screw carries the coal from the storage bin to the hopper of the stoker. Then the stoker feed screw carries it into the combustion chamber of the heating unit.

10-35. In larger installations, such as central heating plants, the coal is transferred to the stoker hoppers by chutes, as illustrated in figure 14.

11. Liquid Fuels

11-1. With the invention of radar and the placement of radar units in isolated spots, the need arose within the military for a heating fuel that could be easily transported. Coal was not the practical fuel, especially in the arctic regions where

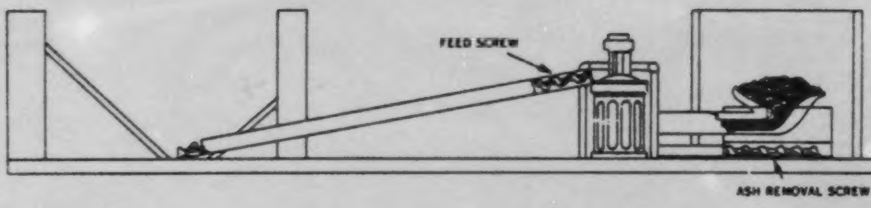


Figure 13. Typical screw feed conveyor tube.

some of the sites are accessible only by air during the winter months. Therefore, liquid fuel was selected for most of these sites, since it is easily transported and can even be dropped by parachute in emergencies.

11-2. The liquid fuel was considerably less expensive to handle than coal and resulted in substantial savings in terms of manhours and money. The use of automatic and semiautomatic firing systems, made possible by the liquid fuel burners, greatly increased the number of heating units that could be safely fired by one man.

11-3. **Characteristics of Fuel Oil.** The most important of liquid fuels is fuel oil. It is composed of combustible liquids and a small amount of noncombustible matter. The standard for designating fuel oils in the United States is issued by the Bureau of Standards of the United States Department of Commerce. The oils are numbered in grades 1, 2, 4, 5, and 6, and titled Commercial

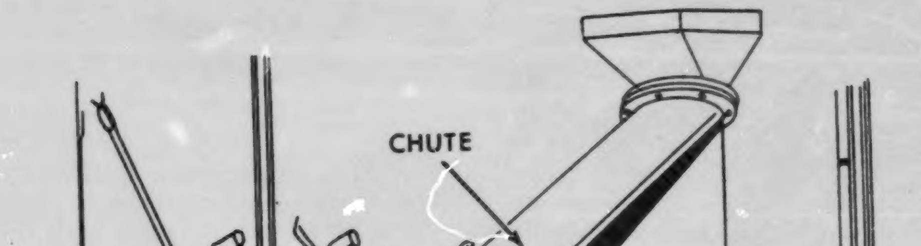


Figure 14. Coal chute and hopper installation.

Standard Grades (CSG). Fuel oil grade 1 is a distillate oil intended for vaporizing, pot-type burners and other burners requiring this grade. Fuel oil grade 2 is a distillate oil for general purpose domestic heating to be used in burners not requiring the grade 1 fuel oil. Fuel oil grade 4 is an oil for burner installations not equipped with preheating facilities. Fuel oil grade 5 is a residual-type oil for burner installations equipped with preheating facilities. Fuel oil grade 6 is an oil for use in burners equipped with preheaters, thereby permitting the use of a high-viscosity fuel.

11-4. *Viscosity.* Fuel oil is stable at normal temperatures, and its evaporation at these temperatures is relatively unimportant. Pumping characteristics of fuel oil at mild temperatures are similar to those of water. However, precautions must be taken to protect tanks and piping in cold climates. This is because fuel oil thickens at low temperatures, and heat must be supplied to heavier grades of fuel oils by using steam coils. This permits normal movement through the piping.

11-5. *Expansion.* The pressure in a closed section of a system, pipe line, or hose increases rapidly with a substantial temperature rise, because fuel oils expand. Unless this excessive pressure is relieved, leakage or permanent damage to valves, meters, and other pieces of equipment can result. In a mechanical storage system, enough air space should remain in the tank at all times to allow for this expansion. You will find that air is forced from the vents when the temperature rises and re-enters the tank when the temperature decreases. When sufficient airspace is not provided for expansion, the tank overflows as the oil expands and creates a fire hazard. The tank vents are installed to allow air to leave and enter the tank as required. These vents must be kept clean to avoid damage to the supply system.

11-6. *Flammability.* **Gas and vaporized fuel oil heated to ignition temperature are combustible when mixed with the proper amounts of air. If ignition occurs inside a container or within a confined space, destructive pressures usually develop. Although fuel oil does not vaporize as easily as gasoline, the dangers caused by the accumulation of vapors in low areas or confined spaces are serious. Fuel oil vapors are heavier than air and tend to settle into pits and low areas, creating mixtures which are fire and explosion hazards. Fuel oil is lighter in weight than water and spreads over the surface of water. This condition also creates a fire hazard.**

11-7. *Chemical effects.* Although fuel oil does not deteriorate lubricants, rubber, and pump seals as rapidly as does gasoline, all materials coming in contact with fuel oil should, nevertheless, be resistant to this deterioration.

11-8. **Unloading Fuel Oil.** When unloading or drawing fuel, you should take every precaution to insure that no static electricity exists in the vicinity of this operation. A spark caused by static electricity can cause an explosion that can result in death or serious injury to you or your fellow workers and damage or destroy government property. The danger of fire or explosion can be minimized by making sure that the railroad car, the fuel oil truck or trailer, and the fuel tank are grounded while the fuel transfer is being made.

11-9. **Storing Fuel Oil.** Fuel oil is usually stored at central heating plants and at individual buildings where oil burners are utilized for heat. The storage tanks should be large enough to hold at least 1 week's supply of oil, estimated at the maximum rate of consumption. The availability and dependability of delivery will also affect the amount of storage space to be provided. The tank for small burners may be the elevated type, erected either indoors or outdoors, with a single-pipe gravity oil feed line used to supply the burners. Steel fuel oil tanks placed aboveground are usually positioned on concrete foundations or columns. A typical aboveground fuel oil storage tank installation is shown in figure 15. When underground steel fuel oil tanks are used, they should be installed at least 2 feet or more below grade. The distance may vary with the type of installation. A typical underground steel fuel oil tank installation is shown in figure 16.

11-10. Filler pipes for steel fuel oil storage tanks should be large enough to permit rapid filling. For safety, they should be at least 5 feet away from all building openings on the same or lower levels.

11-11. Vent pipes are also sized for the desired rate of filling. They extend higher than the filler opening and are equipped with a waterproof head and screen. No connections are permitted to be made from them to any other pipe. The vent openings are located as far as possible from buildings and all sources of ignition. Most installations will have a supply line running from the tank to the burner and another line to return the excess oil from the burner to the tank. The openings for both lines should clear the bottom of the tank by several inches to prevent any interference by the formation of sludge.

11-12. Cleaning the tank is not required when a change is made in the grade of the same type of fuel oil stored in a tank. However, every effort should be made to remove all of the old oil in the tank before refilling it with the new fuel oil.

11-13. **Preheating Fuel Oil.** Heavy fuel oil grades 5 and 6 are used on central heating plant oil burners along with lighter weight fuel oils. Preheating these oils to reduce their viscosity decreases the pumping power required, the wear on the

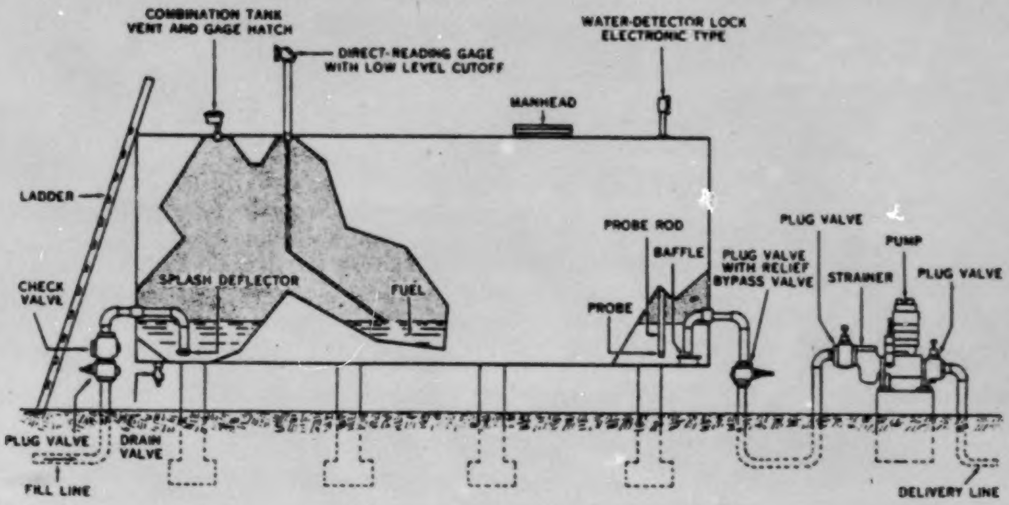

COMBINATION TANK VENT AND GAGE HATCH
DIRECT-READING GAGE WITH LOW LEVEL CUTOFF
WATER-DETECTOR LOCK ELECTRONIC TYPE
MANHEAD
LADDER
PROBE ROD
PLUG VALVE
PUMP
BAFFLE
PLUG VALVE WITH RELIEF BYPASS VALVE
STRAINER
PLUG VALVE
CHECK VALVE
SPLASH DEFLECTOR
FUEL
PROBE
PLUG VALVE
DRAIN VALVE
FILL LINE
DELIVERY LINE

Figure 15. A typical aboveground oil storage tank installation.

pumps, and the size of the pipe necessary to handle the oil. The heating also improves combustion. Preheating is usually accomplished in one, two, or three stages, as required. Stored oil can be heated by steam, hot oil, hot water, or electricity.

11-14. *Steam preheaters.* Two general types of steam preheaters are in common use for heating fuel oils. One type is constructed so that the fuel oil passes through coils that are heated by steam surrounding the coils. The other preheater is just the reverse. In this preheater, the steam passes through the coils and heats the fuel oil surrounding the coils.

11-15. *Hot-oil preheating.* In this method of preheating, a certain amount of the tank oil is heated by the heating plant and returned to the fuel storage tank. Also, the return line is close to the suction line so that the fuel supply line will absorb heat from the return line.

11-16. *Hot-water preheaters.* Hot-water preheaters are similar in construction to steam preheaters. The main difference between this method and the steam preheating method is the use of dif-

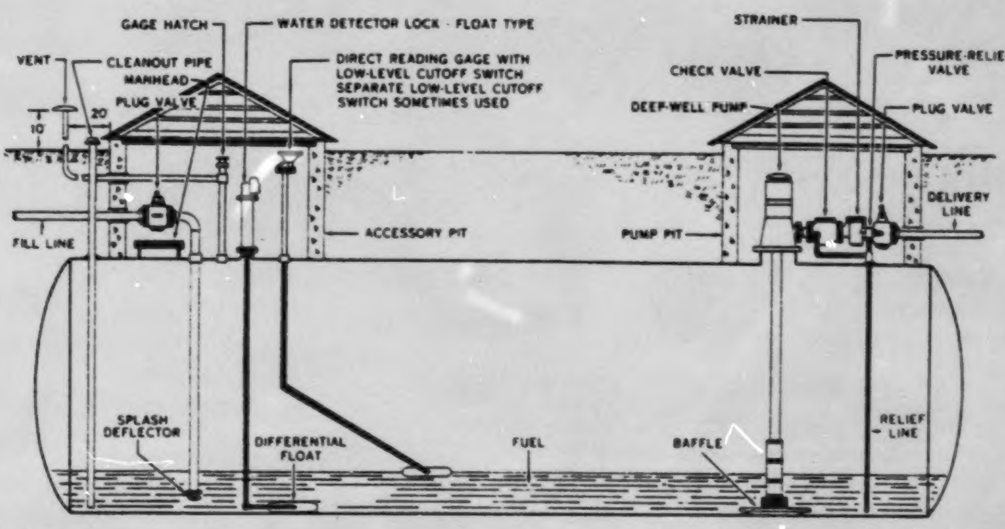

GAGE HATCH
WATER DETECTOR LOCK - FLOAT TYPE
VENT
CLEANOUT PIPE
MANHEAD
PLUG VALVE
20
10
DIRECT READING GAGE WITH LOW-LEVEL CUTOFF SWITCH SEPARATE LOW-LEVEL CUTOFF SWITCH SOMETIMES USED
STRAINER
CHECK VALVE
PRESSURE-RELIEF VALVE
DEEP-WELL PUMP
PLUG VALVE
FILL LINE
ACCESSORY PIT
PUMP PIT
DELIVERY LINE
SPLASH DEFLECTOR
DIFFERENTIAL FLOAT
FUEL
BAFFLE
RELIEF LINE

Figure 16. A typical underground fuel tank installation.

ferent mediums of heating—hot water instead of steam is used to heat the fuel oil.

11-17. *Electric preheaters.* Electric preheaters are seldom used when either steam or hot water is available as a heating medium. Electric preheaters are usually installed directly on the oil burner. But all of the above methods can be used to preheat fuel oils in the storage tanks as well as in the feed lines. Usually, a fuel system will be provided with at least two or more means of heating fuel oil. One means may be provided for the storage tanks and another for the feed lines, while a third may be installed on the burner.

11-18. In many heating systems, a remote bulb thermostat is used to control the temperature of the fuel oil in the storage tanks, fuel lines, and burners.

11-19. **Maintaining Fuel Oil Storage Tanks.** An empty fuel oil storage tank should never be entered by personnel without permission and instructions from the proper authority. It is seldom necessary to clean a fuel oil tank until the sludge becomes excessive, the interior of the tank becomes excessively corroded, or the tank has to be repaired. When fuel oil tanks are cleaned, certain safety precautions must be complied with and certain methods followed. Information concerning these will be supplied by your supervisor.

11-20. **Types of Fuel Oil Supply Systems.** Oil is transferred from the storage tanks to the burners by either force pumps or gravity. Since it is not practical to maintain accurate regulation to compensate for varying loads, provision must be made in some systems to return the unused oil to the storage tank or to recirculate it through the supply system. The following paragraphs are devoted to a discussion of some of the commonly used types of fuel oil supply systems.

11-21. *Single-pipe, gravity-feed oil supply system.* Single-pipe, gravity-feed oil supply systems are used in small space heater installations. An illustration of this type of system is shown in figure 17. In this system, the oil storage tank is installed at a higher level than the burners. This allows the oil to flow to the burners by gravity. No provision is made for the return of unused oil to the storage tank, since the oil flow is controlled by the amount that is used by the burner.

11-22. *Single-pipe, forced-feed oil supply system.* The single-pipe, forced-feed oil supply system is normally used it is impossible to use a one-pipe, gravity-feed system. In this type of system, the storage tank is usually below the level of the burner. An oil pump, usually a positive displacement type, is installed in the system to force the fuel oil to the burner. This system recirculates the unused oil through the pump.

11-23. *Double-pipe, gravity-feed, forced-return oil supply system.* Fuel oil supply systems of this type are designed for larger installations than those mentioned previously. The fuel supply line in this system is essentially the same as for a single-pipe, gravity-feed system. The difference between the

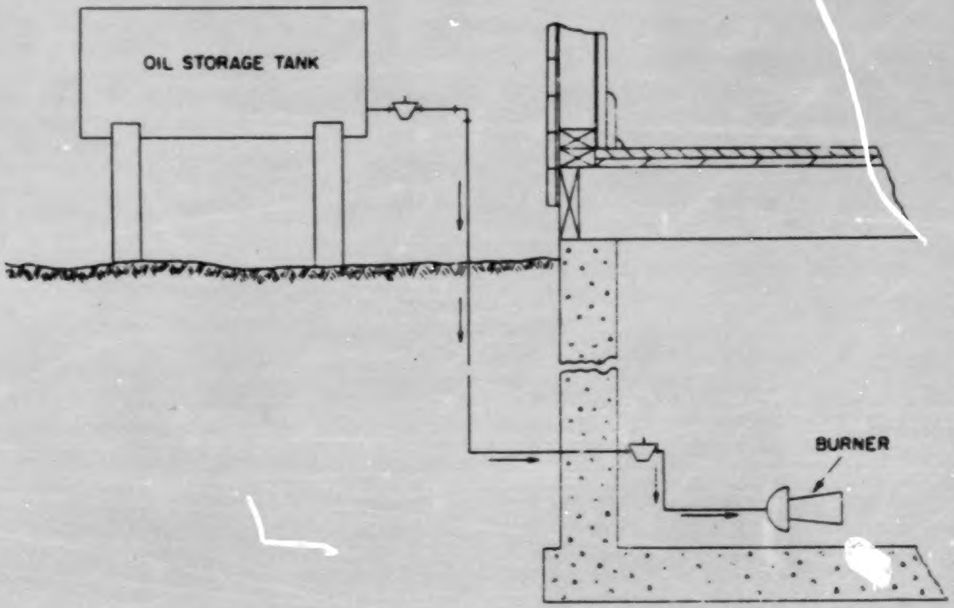


Figure 17. A single-pipe, gravity-feed fuel oil supply system.

28

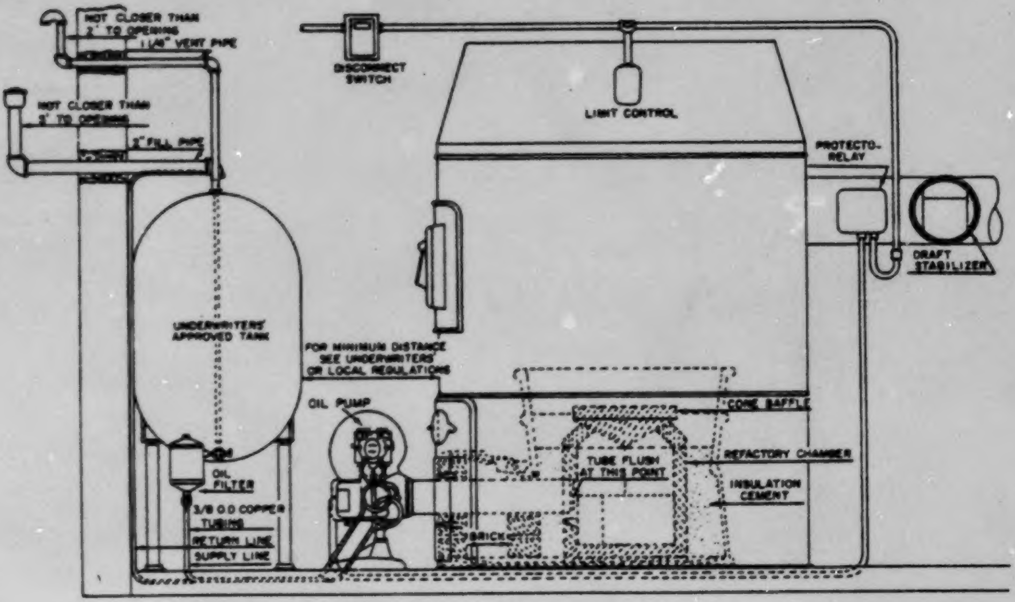

NOT CLOSER THAN
2' TO OPENING
1 1/4" VENT PIPE
NOT CLOSER THAN
2' TO OPENING
2" FILL PIPE
DISCONNECT SWITCH
LIMIT CONTROL
PROTECTO-RELAY
DRAFT STABILIZER
UNDERWRITERS' APPROVED TANK
FOR MINIMUM DISTANCE SEE UNDERWRITERS' OR LOCAL REGULATIONS
OIL PUMP
CONE BAFFLE
REFACTORY CHAMBER
TUBE FLUSH AT THIS POINT
INSULATION CEMENT
OIL FILTER
3/8 O.D COPPER TUBING
RETURN LINE
SUPPLY LINE
BRICK

Figure 18. A double-pipe, gravity-feed fuel oil supply system.

two systems lies in the methods of handling excess fuel oil. This is accomplished in this system by the addition of a fuel oil return line. Figure 18 shows a diagram of this system. Extreme care must be exercised when operating a system of this type, since failure of the return pump can cause the burner to flood, thus forming a pool of oil in the combustion chamber.

11-24. *Double-pipe, forced-feed, gravity-return oil supply system.* This type of supply system is perhaps the most common found in central heating plants. A diagram of it is shown in figure 19. This system is similar to a two-pipe system. The fuel oil is forced to the burner by a pump, and the excess oil is returned to the storage tank by gravity.

11-25. **Units of a Fuel Oil Supply System.** Some of the essential units in a fuel oil supply system, besides the storage tanks and piping, are the pumps, valves, and strainers.

11-26. *Pumps.* The pumps used in fuel oil supply systems are piston, gear, centrifugal, and turbine types. They are used either to pump fuel from the storage tanks to the burner or to pump the excess oil from the burner to the storage supply tank. A pressure relief valve is generally used on the discharge line.

11-27. *Master valves.* Master valves in the burner manifold control the fuel oil flow to the burners. In addition, each line supplying fuel to a burner is equipped with an individual stop valve.

11-28. *Strainers.* It is essential that the fuel oil supplied to oil burners is clean; otherwise, the passages in the burners will clog. Fuel oil is kept clean by means of oil strainers. A typical duplex fuel oil strainer is shown in figure 20. This unit has two strainers in one body. It is constructed in such a manner that the flow of fuel can be directed through either of the strainers by the use of the hand lever. In this way, one strainer can be cleaned while the other is in use.

11-29. **Maintenance of Fuel Oil Supply Lines.** The fuel oil supply lines should be checked for leaks by starting each pump in succession. This inspection should include the nuts on all valves, strainer caps, plugs and caps on air chambers, pump shaft packing, storage tank connections and fittings, all exposed piping, and controls. The pumps should be inspected for vibration and noise, and their packing should be replaced as required. All of the strainers should be cleaned at the recommended intervals by using steam, hot water, or solvent. When air pressure is used, care should be taken not to damage the strainer. The valves in the system must be inspected for proper operation and be lubricated as required.

11-30. Any unusual condition or evidence of abuse of the fuel oil supply system should be reported at the time that it is first noticed.

12. Gaseous Fuels

12-1. The use of natural gas as a fuel is not altogether new. As a matter of fact, this has been known from a very early date—perhaps even before recorded history. Natural gas, however, did

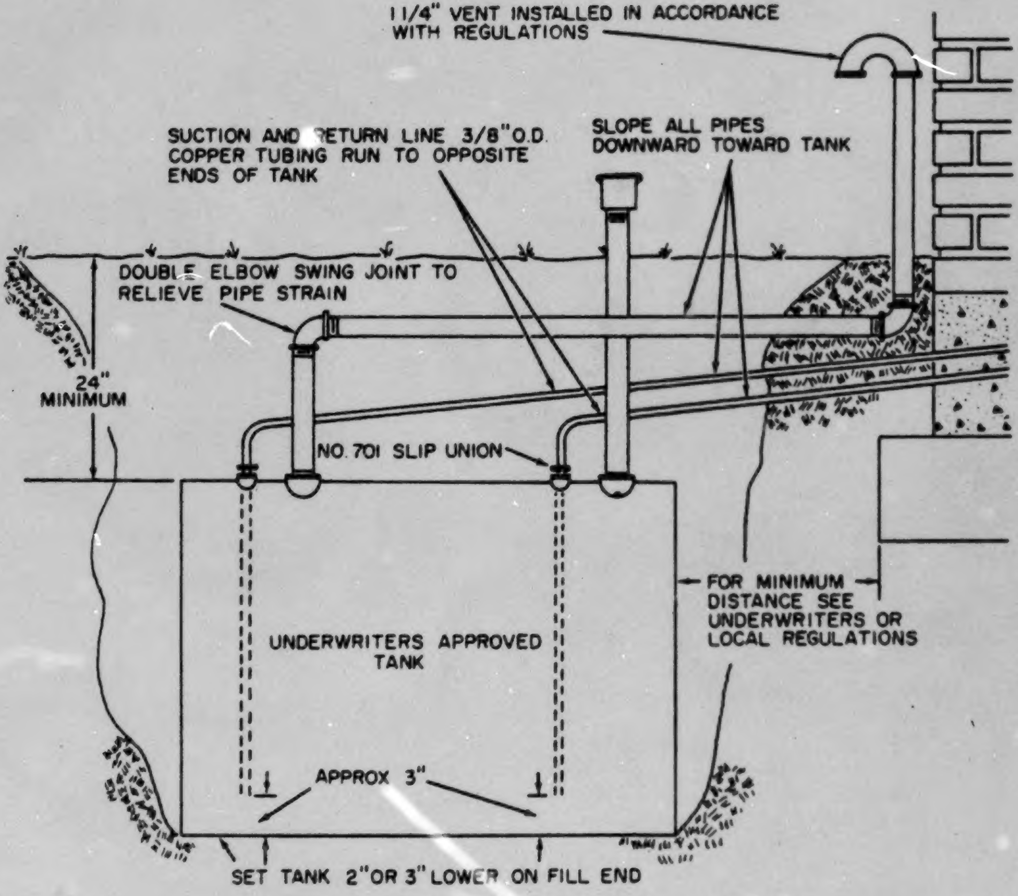

1 1/4" VENT INSTALLED IN ACCORDANCE WITH REGULATIONS
SUCTION AND RETURN LINE 3/8" O.D. COPPER TUBING RUN TO OPPOSITE ENDS OF TANK
SLOPE ALL PIPES DOWNWARD TOWARD TANK
DOUBLE ELBOW SWING JOINT TO RELIEVE PIPE STRAIN
24" MINIMUM
NO. 701 SLIP UNION
FOR MINIMUM DISTANCE SEE UNDERWRITERS OR LOCAL REGULATIONS
UNDERWRITERS APPROVED TANK
APPROX 3"
SET TANK 2" OR 3" LOWER ON FILL END

Figure 19. A double-pipe, forced-feed, gravity-return fuel oil supply system.

not come into its own for a great many years after this. For a long time, fuel experts were far more interested in manufactured gas made from coke and oil. Manufactured gas was the chief gaseous fuel throughout the nineteenth century, and it is still being used in various communities. Although natural gas was not a serious competitor of manufactured gas until the twentieth century, it was being used in this country on a modest scale in the 1820's.

12-2. There are three principal types of gaseous fuels commonly used for heating purposes. These gases are natural, blast-furnace, and liquefied petroleum.

12-3. **Natural Gas.** Natural gas is perhaps the closest approach to the ideal fuel. Scientists still are not absolutely sure how natural gas came to be stored in the crust of the earth. But, according to the generally accepted theory, countless numbers of plants and animals have been deposited on the ocean floor throughout the ages. The layers of animals and plants have in turn been covered by layers of dirt or mud. As thousands upon thousands of years have passed, the weight of more and more layers of dirt have built up the terrific pressures and created the heat which have had their effect upon the remains of these plants and animals. It is believed that this action has been responsible for converting them into gas and oil.

12-4. The first natural gas well to be drilled in the United States was located in Fredonia, New York, in 1821. It was not until some time later that natural gas became popular as a heating fuel. Natural gas finally came to the front as a heating fuel following the discovery of new gas fields, and as more efficient means of transportation were developed.

12-5. Gas burns efficiently and clean, and the flow of gas can be easily controlled automatically. Thus, it cuts operational costs by eliminating the

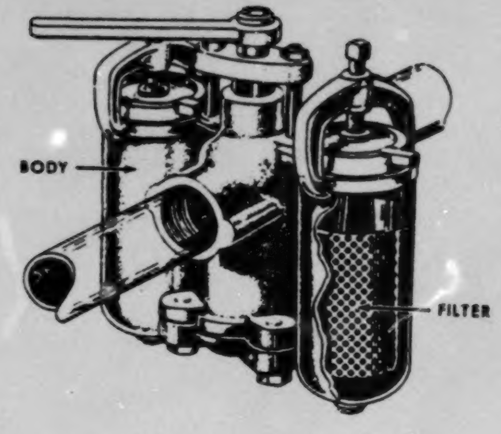


Figure 20. A typical duplex fuel oil strainer.

need for full-time operators, except in very large plants. A major drawback to using natural gas is that it is not always feasible to store it in containers aboveground. Consequently, when the gas supply is interrupted, another fuel must be temporarily substituted. Natural gas is, however, stored deep underground in great quantities by gas companies during the summer for use during the winter or when consumption is greatest.

12-6. *Natural gas fuel supply systems.* The natural gas fuel supply systems for natural gas heating units are unlike those for oil burning units. Most gas burner fuel systems consist of a master shutoff valve, pressure regulator, gasmeter, and piping. Other gas controls, either manual or automatic, usually are a part of the heating unit.

12-7. *Installation of natural gas fuel supply systems.* The master shutoff gas valve is usually located in the gas supply line at the point where the line enters the building or other installation. It is used to shut off the gas to the heating units. The pressure regulator is normally installed next to the gas shutoff valve. The regulator is used as a station to reduce the high gas pressure in the line. In some cases, the gas pressure is reduced through several stations—each station reducing the pressure slightly. This is done so that when one station fails, the rest of the stations will have some control over the flow or pressure. The gas meter is usually installed in the line next to the pressure regulator. The purpose of the meter is to record the amount of gas used.

12-8. Safety should be the main factor of construction when locating new gaslines. The lines should not be located in unventilated spaces under floors, in walls, or in attics, etc. A gas leak in an unventilated confined area can result in an explosion. Gaslines, located either above or below the ground, should not be exposed to freezing weather. Steel pipe and fittings of malleable iron or forged steel can be used in gas systems because of the low gas pressures. Gas pipes should be securely fastened and supported with hooks, straps, bands, or hangers at intervals of not more than 8 to 10 feet. This, of course, depends upon the pipe size.

12-9. Gaslines from the main supply to the burner should be graded at least 1 inch for every 50 feet of pipe to prevent water from collecting in the lines. The main gas valve should be installed outside a building, so that it is easily accessible in case of a fire inside the building. The trend in present-day building construction places both the main gas valve and the gas meter near the outside of new construction. Gas pipes should never be used as part of an electrical grounding system—cold water pipes are preferred.

12-10. With the system under pressure, a leak test should be made at each connection before placing a new installation into service. A solution of soapy water is applied with a brush at each joint when checking for gas leaks. A soap bubble will form at the joint if a gas leak exists.

CAUTION: A lighted match or candle must never be used to check for gas leaks, since the escaping gas is apt to ignite and cause an explosion and a fire.

12-11. *Maintenance of natural gas fuel supply systems.* Very little maintenance is required on natural gas fuel systems other than checking for gas leaks, the vibration of piping, and the rusting of black iron pipe.

12-12. **Blast-Furnace Gas.** Blast-furnace gas is a byproduct of blast-furnace operation. It is a lean gas with low heating value, and it is produced only in varying quantities. It must be used as fast as it is produced, because of its instability, and it can be piped only comparatively short distances from the producing furnace. For this reason, its use for heating is limited to those installations near the producing plant.

12-13. This kind of gas carries a large amount of dust and must be partially cleaned before it is used. Usually, the heating units which burn blast-furnace gas have oversize combustion chambers, because such large quantities of gas must be burned to obtain the minimum amount of heat. Blast-furnace gas supply systems differ in design from natural gas installations, and the variance depends upon the heating value of the gas.

12-14. **Liquefied Petroleum Gas.** The use of liquefied petroleum (L.P.) gas—such as butane and propane—for cooking, for processing, and for heating purposes is increasing rapidly. This manufactured gas is usually more expensive than other types of gas. However, the ease with which it can be transported to localities far distant from the gas manufacturing plants has increased its popularity.

12-15. Liquefied petroleum gas is compressed at the refinery into suitable containers to pressures up to 200 pounds per square inch. At high pressures, the gas is changed to a liquid. When the gas is used, the pressure is reduced to approximately 6 to 8 pounds per square inch. This reduction in pressure causes the liquid to change back to a gas. The L.P. gas is readily combustible and produces intense heat. In the pure state, it is odorless; however, an odorant is added to insure its detection in case of a leak in the tank or piping.

12-16. Liquefied petroleum gas supply systems are similar to natural gas supply systems. However, this gas is obtained from a tank located near the heating unit, while nautral gas is piped in from gas fields. Installation procedures for the supply line running from the tank to the heating unit are similar to those for natural gas lines. In most cases, the pressure regulator and the main valve are located in the line near the tank. No gasmeter is utilized in this system; however, a gas gauge located on the tank serves to indicate the amount of gas left in the tank.

12-17. The maintenance required for liquefied petroleum fuel systems is practically the same as for maintaining natural gas fuel systems. Liquefied petroleum gas is heavier than natural gas and, therefore, quickly settles into low places. For this reason, all of the valves and connections should be tight enough to prevent gas leaks. A soap solution should be used to check the system for leaks. *A flame should never be used when checking for leaks.*

Heating Unit Installation

THE EARLIEST forms of heating homes were direct methods. They included the open fires with which primitive men warmed their dwellings. Some types of stoves and braziers (pans for holding burning coals) were adopted by the Romans and are still employed in various parts of the world. In the colder portions of Europe, the fireplace was developed as a method for heating rooms by means of an open fire. The first fireplaces were hearths with short flues recessed into the walls of buildings. Fireplaces with high chimneys, which rose above the roof of the building and provided adequate draft to keep the fires on the hearth burning brightly, were introduced during the 12th century. Fireplaces of today consist of a hearth closed on three sides with brick, surmounted by a completely inclosed chimney or flue which carries away the smoke and combustion products of the fire. On the hearth is a metal grate raised on legs, or a pair of metal supports called *firedogs* or *andirons*. Grates, to permit the circulation of air under the fuel for combustion purposes, are used when coal or coke is used for fuel.

2. The useful heat given off by a fireplace consists of the heat radiated directly by the burning fuel and that which is absorbed and reradiated by the side and back walls. From 85 to 90 percent of the heat from burning fuel is lost in the combustion gases and smoke which go up the chimney. The inclusion of fireplaces in modern houses is for beauty and style rather than for their thermal efficiency.

3. In this chapter, you will read discussions on types of coal, oil, and gas space heaters which are more efficient heat producers than the fireplace. You will also study the installation, operation, and maintenance of these heaters. You may be called upon at any time to install, operate, or maintain any one of these various types of space heaters. When you do have such an assignment, your supervisor will expect you to have a working knowledge of the type and of the fuel required to operate the heater. By gaining the knowledge contained in this chapter, you will be able to better understand the construction, operation, and maintenance of the more complicated heating equipment you will use throughout your Army career.

13. Space Heating

13-1. A space heater—or stove, as it is sometimes called—is an inclosure of metal or ceramic materials in which fuel is burned to provide heat. It is an improvement over the fireplace because its radiating surface is relatively larger and in contact with the air of the room, and because it gives a certain amount of heat by air convection, as illustrated in figure 21. An efficient modern space heater utilizes about 75 percent of the heat of the fuel burned in it. In rural areas of the United States and many other parts of the world, space heaters are still being used extensively for heating houses. The fuels burned in these types of heaters include wood, coal, coke, peat, oil, and gas.

13-2. Since the space heater is not a permanent installation, it can be located in a desirable place in the center of a room to provide the greatest amount of heat. However, the space heater is not very satisfactory in providing comfortable heat for a large space, because of the method of heat distribution. The simplicity of construction, the low initial cost, and the low fuel consumption—regardless of whether it is coal, gas, or oil—make the space heater desirable as a means of providing heat for small areas.

13-3. **Types of Coal-Fired Space Heaters.** Coal-fired space heaters or stoves are used in areas where coal is plentiful and cheaper than other fuels. They are sturdy in construction and require very little maintenance. The major disadvantages in using coal-fired space heaters are that they are manually operated, they present ash-removal problems, and the area surrounding them is difficult to keep clean.

13-4. Two types of coal-fired space heaters commonly used by the military are the cannon stove and the magazine stove. The cannon stove is side-stoked, of potbelly design, and depends upon radiation for its heating effect. The magazine stove is top-stoked, has steel jackets around the firebox, and depends primarily upon the circulation

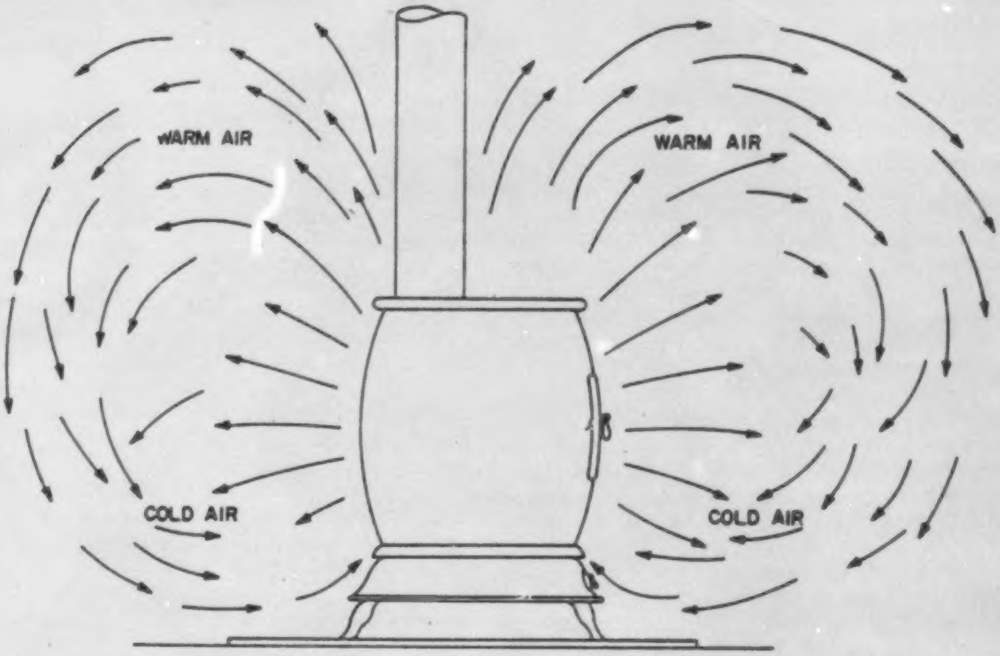


Figure 21. Convection currents around a space heater.

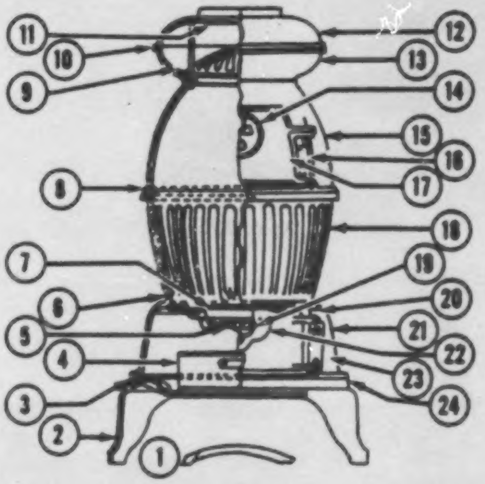
of air around the jacket and firebox for heating action.

13-5. *Cannon stove.* The cannon stove shown in figure 22 is the space heater that is commonly known as the *potbelly* stove. It is constructed entirely of cast iron sections, which make it easy to transport and assemble. The major component parts of the cannon stove are the ashpit, firepot, barrel, topneck, and topcollar. Figure 22 also shows the other major parts of the stove.

13-6. The ashpit section serves as a base for the heater. It forms a compartment which catches the ashes as they fall through the grates into the ashpan. The ashpit section is supported by legs which keep the section from direct contact with the floor and thereby reduce the fire hazard.

13-7. The firepot, of circular construction, is that part of the heater where the coal is burned. The grates are located directly above the ashpit in the lower part of the firepot. They are of finger-type construction and circular in shape. The movement of the grates is controlled by a shaker-lifter, which is inserted through an opening at the front of the ashpit. Shaking the grates removes the ashes and allows air to reach the fire.

13-8. The barrel of the stove, to which the feed door is attached, is located directly above the firepot section. The topneck and topcollar, to which the heater flue is attached, are supported by the barrel. The barrel, the topneck, and the topcollar



1. SHAKER LIFTER
2. LEG
3. CEMENT SEALER
4. ASHPAN
5. DRAW GRATE
6. CEMENT
7. ROUND GRATE
8. CEMENT SEALER
9. BAFFLE
10. COVER SEALER
11. COVER
12. TOPCOLLAR
13. TOPNECK
14. FEED DOOR DRAFT PLATE
15. BARREL
16. HINGE PLATE
17. FEED DOOR
18. FIREPOT
19. YOKE
20. ASH DOOR
21. ASHPIT
22. ASH DOOR DRAFT PLATE
23. HINGE PLATE
24. BOTTOM

Figure 22. The cannon stove.

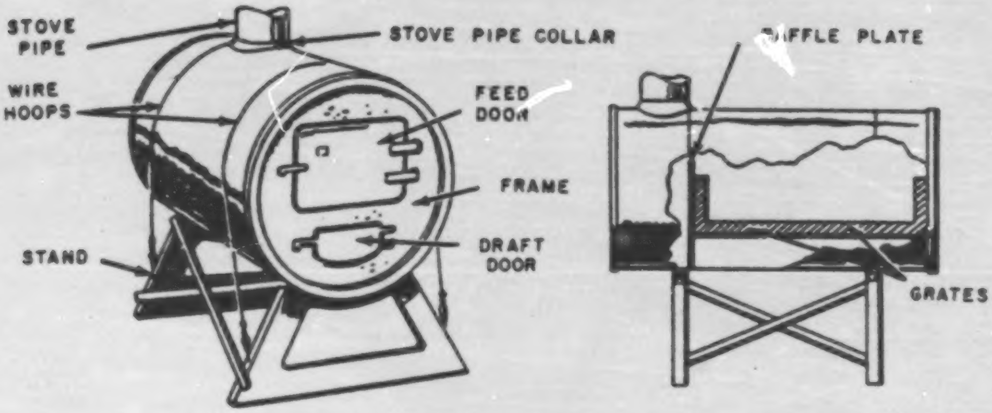


Figure 23. Theater-of-operations space heater.

serve as the principal means of heat radiation. The stove is fired by hand through the front feed door. Always check the fuel for dirt, metal, and glass before firing, and never allow ashes to pile up in the ashpit, because the grates will burn out. When removing ashes, put them in metal or cement containers, since they are a fire hazard.

13-9. *Magazine stove.* The magazine-type coal-fired space heater is an improvement over the cannon stove. The one commonly used is the U.S. Army No. 1 space heater. It is called a *magazine stove* because the greater portion of the body (above the grates) is a reservoir, or *magazine*, for holding a large quantity of coal.

13-10. The drum, or main part of the body, is made of sheet steel, lined with firebrick and special flue brick to prevent damage to the sheet steel by the heat. The top, doors, grates, legs, and base are made of cast iron. The U.S. Army No. 1 space heater holds about 100 pounds of coal, and it will operate for several hours.

13-11. Most models of the magazine-type space heater are equipped with a heat exchanger. This is a large, oval-shaped sheet metal section (located at the entrance to the smokestack) which helps make use of the heat that ordinarily is wasted by going out the smokestack. The heat exchanger greatly increases the heater's efficiency.

13-12. The magazine stove uses a barometric damper in the smokepipe. This is a weighted damper that maintains a constant draft, regardless of wind and temperature. It helps prevent overheating and conserves fuel.

13-13. *Theater-of-operations space heater.* The theater-of-operations space heater is a conversion space heater constructed from a 55-gallon oil drum. It is shown in figure 23. A kit for converting an oil drum into a space heater is manufactured, and it can be procured through the proper supply channels. The conversion kit consists of the items shown in figure 24. The instructions which are furnished by the manufacturer with each conversion kit describe the assembly, installation, testing, and operation of the heater.

13-14. **Installing Coal-Fired Space Heaters.** Space heaters are more efficient when they are located in the center of the area to be heated. Heat distribution is not as effective if they are installed near walls.

13-15. When installing space heaters, some type of insulation which extends a reasonable distance beyond the sides of the heater should be placed between the heaters and floors of combustible materials. In some cases, the insulation is a piece of sheet metal, and in other cases it is a bed of sand in a metal frame. The insulation is used as a precautionary measure against fires that can be caused by sparks and burning coals. A space heater should not be placed near a combustible wall, unless this is absolutely necessary. A sheet of asbestos, or other suitable insulation, and spacers are fastened on the wall next to the heater if the stove is placed closer than 3 feet to a wall. This is another precautionary measure against fires.

13-16. A roofjack or smokejack should be installed after the heater is set in place. The roofjack smokepipe should extend at least 3 feet above the highest point of the building roof. A downdraft hood should be installed to prevent downdrafts caused by an adjoining building, a tree, or terrain features. Downdrafts can cause serious interference with the proper function of the heater, and the roofjack smokepipe should terminate with a suitable hood. A specially designed downdraft hood can be installed when it is necessary to increase updraft.

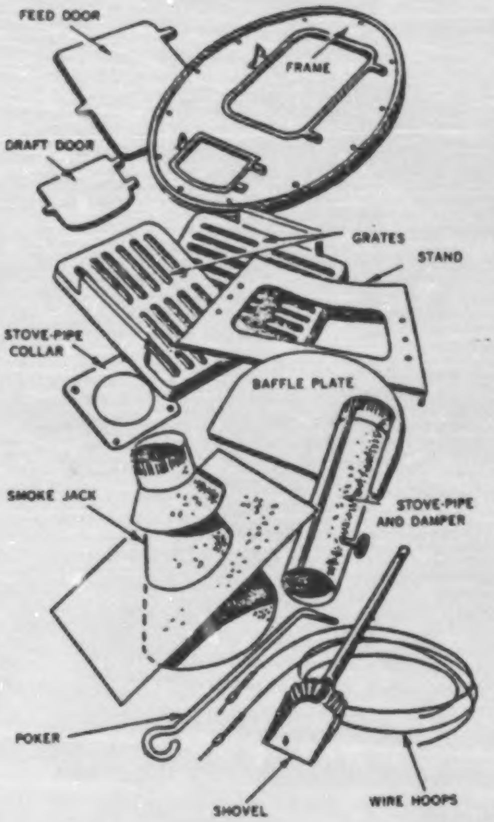


Figure 24. Conversion kit for a theater-of-operations space heater.

13-17. The smokepipe between the heater and the chimney must be of the proper diameter and must be installed in a direct line to the chimney, with as few bends and joints as possible. This is done to reduce resistance to the flow of smoke. The pipe joints should fit tightly to prevent smoke fumes from escaping into the building, and the pipe should be held securely by placing at least three sheet metal screws through each joint. The complete assembly of smokepipe is usually held in place by smokepipe wire, fastened to the walls or ceiling with screweyes. A smokepipe damper is usually installed in the first joint of pipe above the heater.

13-18. When you are installing magazine-type space heaters, you should be very careful in loading, unloading, and moving. Never roll or slide the units, as this might break the legs and disturb the firebrick. You should always check the firebrick liners for proper position and condition. In addition, you should follow the pertinent instructions issued by the manufacturer and the Army when installing coal-fired space heaters.

13-19. **Operating Coal-Fired Space Heaters.** Coal-fired space heaters require more frequent attention than oil-fired and gas-fired space heaters. The coal on the grates receives primary air for combustion through the grates from the ashdoor draft intake. Combustible gases are driven from the coal by the heat, and these burn in the barrel of the stove. Here they receive additional or secondary air through the feed door. The side and top of the stove absorb the heat of combustion and radiate it to the surrounding space.

13-20. Ashes tend to pile up above the grates and restrict the flow of air necessary for efficient combustion. Not only that, the fire bed will gradually be raised to a point where the fire is burning up in the barrel of the stove instead of in the firepot as more coal is added. This condition can cause the barrel to be overheated and the stove to be ruined beyond economical repair. It is essential, therefore, that the grates be *shaken* at intervals. Shaking the grates sifts the ashes down through the grates into the ashpit, where they can be removed.

13-21. The ashes should be removed from the ashpit before they become piled up against the undersides of the grates. Air flowing up through the grates keeps them fairly cool, but if the flow of air is restricted by ashes, the grates become so hot they will warp out of shape. When this happens, you have "burned out" grates which must be replaced.

13-22. In addition to adding more coal, shaking the grates, and removing ashes, the operator must keep the draft adjusted to meet the needs of the fire. He does this by adjusting the sliding openings in the ashpit door and the fuel supply door. Too much draft will overheat the stove, causing ashes to fuse into clinkers, and too little draft can cause the fire to go out.

13-23. The smokepipe damper is also used to control the draft and the rate of fuel consumption. If it is a windy day and the smokepipe damper is fully open, the increased draft can increase combustion to the point where the smokepipe will become red hot and set fire to the soot in the chimney. This, in turn, could set fire to the building. It is not safe to leave a coal-fired space heater unattended for a long period of time.

13-24. The magazine-type space heater operates on the beehive coke-oven principle. With the fire started and the magazine filled within 3 inches of the top of the flues, the coal directly above the fire is heated and coked. Combustible gas driven off in this process will burn while passing through slots and behind the firebrick flues into the side combustion chambers. Primary air is supplied upward through the grates and secondary air is sup-

FIREMAN'S PERFORMANCE CHART

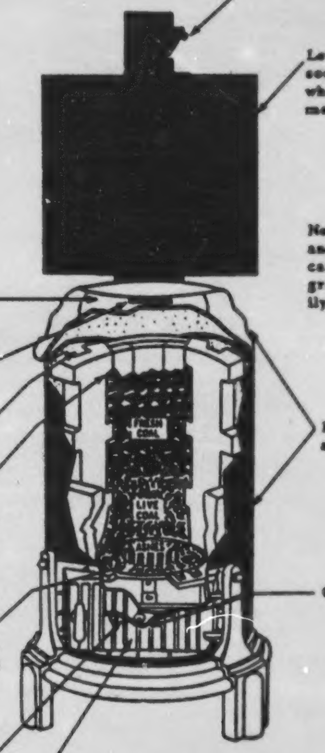
NR 1 & NR 4 ARMY SPACE HEATERS

STARTING A FIRE

1. Clean grate and ashpit.
2. Put 6 inches of coal on grate.
3. Place kindling and paper on coal and light.
4. Close coal feed door and ashpit door.
5. Open draft door in ashpit door and secondary air draft slide in coal feed door.
6. When coal is burning well, fill half full and close ashpit draft door half way.
7. When fresh coal is burning well, fill magazine to within 3 to 6 inches of top and adjust draft door to keep room comfortable.

REGULAR FIRING

1. Keep coal feed door closed except when adding coal. Stand to one side when opening feed door.
2. Secondary air draft slide should always be open. (Not provided on all heaters.)
3. Keep coal and ashes out of side flues by cleaning daily. Use cleaning rod carefully.
4. Fill magazine to 3 inches below top of firebrick at each firing unless fire is to be allowed to go out that day. Use coal scoop to avoid spilling coal into side flues.
5. Ashes on the grate protect it and help control the fire. Shake grate gently from side to side until faint red glow appears. Pull out dump grate only to dump fire or large clinkers. Clean ashpit immediately after shaking grate.
6. Control fire and heat with small air door in ashpit door. Open just enough to keep room comfortable except when building a new fire.
7. Keep ashpit door closed tight by tightly closing latch except when removing ashes.



Barometric damper must operate freely to prevent a runaway fire and overheating and to save coal. (Don't wedge it closed.)

Let fire go out. Remove and empty soot and fly ash from economizer when notified to by post engineer mechanic. (Not used on all heaters)

Never use a poker unless coal melts and bridges across magazine. Then carefully avoid striking brick or grate with pokers as they break easily when hot.

Polish stove body and top as often as necessary to prevent rusting.

TO BANK A FIRE

Close air door in ashpit door.

AVOID FIRE HAZARDS

Keep clothes, trash, paper and other combustible material at least 3 feet from heater.

Never put oil or gasoline into heater or keep it near heater.

IN CASE OF TROUBLE, CALL ________________ PHONE _______

Figure 25. Cutaway of a U.S. Army No. 1 space heater and fireman's performance chart.

plied through the hand-operated damper in the feedbox door. The heater jacket and the top transmit the heat of combustion by radiation and convection to the area adjacent to the heater. Study the chart in figure 25 which shows how to operate the U.S. Army No. 1 magazine space heater.

13-25. **Maintaining Coal-Fired Space Heaters.** Coal-fired space heaters should be inspected in accordance with the base schedule prescribed for such heaters. You should examine the roofjack and the fluepipe from the outside of the building as well as from the inside. Any noticeable deterioration such as rusting, broken guy wires, and the like should be reported and repaired. You should check the dampers for proper operation and adjust them to hold the correct position during their operation. Check the feed and ashpit door hinges and latches for damage. Air should not be allowed to leak between the doors and door frames. You should determine if the heater body is warped, rusted, or deteriorated in any way, and then make needed repairs. The fire pot must be empty for you to examine the grates and shaking mechanisms. If warping or other damage is found when examining the grates and shaking mechanism, the damaged parts should be repaired or the whole assembly replaced as needed. This inspection can usually be accomplished through the feed or ashpit doors. You should always be on guard against fire and safety hazards such as damage to metal-covered asbestos, insulating board, or other protective devices located between the space heater and the building floor. Also, look for combustible materials that are stored too close to the space heater. If any of these hazards exist, report them immediately to your supervisor, who should see that they are corrected.

13-26. **Types of Oil-Fired Space Heaters.** In areas where oil is the principal fuel, oil-fired space heaters are used for many space heating requirements. Essentially, they serve the same purpose as coal-fired units. Oil-fired heaters are of much lighter construction, however, than coal-fired heaters. Particular attention must be given to their care and proper maintenance.

13-27. Oil-fired space heaters are very simple in construction. They consist of a burner, a combustion chamber, an outer casing, a fuel tank, and a fuel control valve. An air space is provided between the combustion chamber and the outer casing. Air that enters through grilles in the bottom of the heater is heated and then passes out through the grilles in the top of the unit.

13-28. Some oil-burning heaters are equipped with a blower and electric motor, which force the heated air into the room. The units turn at slow speeds and are either direct drive or belt driven.

13-29. Oil-fired space heaters have atmospheric vaporizing-type burners, and we shall describe two of these burners. The burners require a lightweight grade of fuel oil which vaporizes readily at low temperatures and leaves only small amounts of carbon and ash. Fuel oil of No. 1 weight is generally used. The two types of oil-fired space heaters that we will be discussing are the perforated sleeve and the pot type.

13-30. *Pot-type oil-fired space heaters.* Natural draft pot distillate burners are widely used for space heaters, room heaters, water heaters, and the like. They account for approximately 90 percent of all space-heating units in use. An illustration of the natural draft pot-type burner is shown in figure 26.

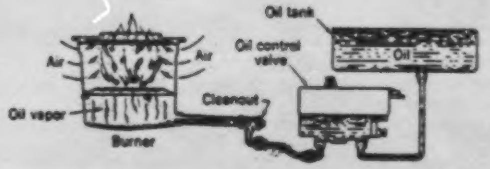


Figure 26. A natural draft pot-type burner.

13-31. A cutaway of the pot-type burner is shown in figure 27. In operation, the distillate (oil) is fed in at the bottom of the burner or pilot casing, located either at the center or on the sides. The fuel is vaporized at this point by radiant heat from above. The vapors rise and are mixed with air drawn through the perforated holes in the burner. During high-fire conditions, the flame is above the top of the combustion ring as shown in figure 28. Under low-fire conditions, the flame burns in the lower portion or pilot ring of the burner, as shown in figure 29. The rate of distillate oil flow and method of ignition are often controlled manually.

13-32. *Sleeve-type oil-fired space heaters.* The sleeve-type distillate burner is shown in figure 30. It includes a metal base formed of two or more circular fuel-vaporizing grooves and alternate air channels. Also included are several pairs of perforated sleeves or cylinders; one is inside, the others are mounted on the metal base. Each pair of perforated sleeves forms a combustion chamber above its grooves. One or more cover plates that rest on top of the nested cylinders baffle the flame and close the air passage. This forces the air through the perforations into the oil vapor chamber. In this way a large number of air jets are introduced into the oil vapor, producing a good fuel mixture. The mixture burns with a blue flame, and it is clean and odorless.

13-33. These burners usually have a short asbestos kindling wick for ease in lighting. Some burners have a cup installed below the base so that alcohol can be burned to provide heat for starting. The wick and the alcohol are used only for lighting.

13-34. **Installing Oil-Fired Space Heaters.** Oil-burning heaters are portable and are easily moved from one location to another. To get satisfactory operation, you should follow the installation procedures supplied by the manufacturer. In both the pot-type and perforated-sleeve burners, oil is fed to the burner under control of a float-operated metering valve such as that shown in figure 31. You must set the unit level so that the oil will be properly distributed in the burner. The fuel

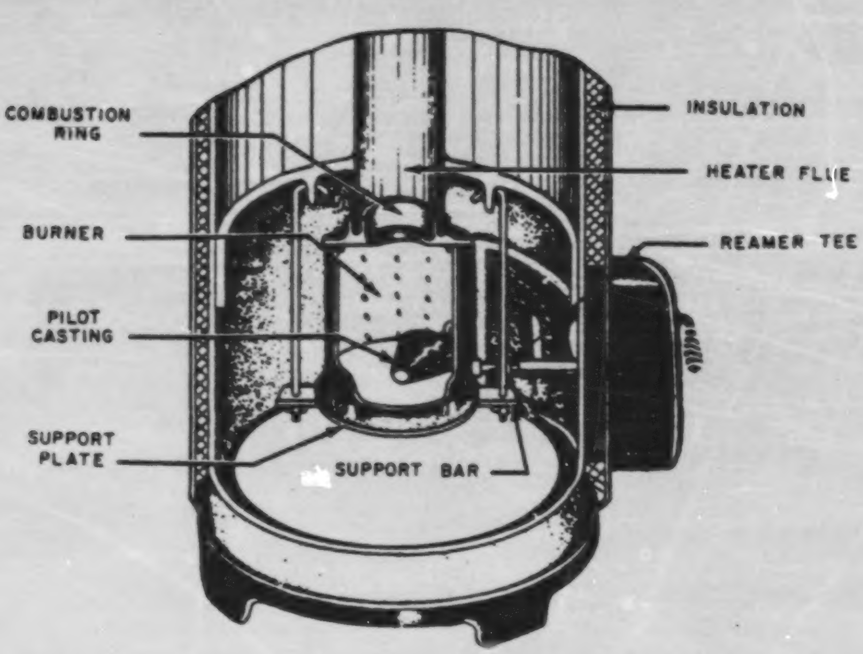


Figure 27. Cutaway of a natural draft pot-type burner.

level control valve is the only safety device installed on the oil-fired space heater.

13-35. An oil supply from an outside tank to all heaters is often desirable when several space heaters are installed in a building. This eliminates frequent filling of individual tanks and reduces the waste from spilling. Figure 32 shows the principal elements of such a system, and it indicates the important points to consider during the installation.

13-36. The heater should be placed the same distance from the wall as a coal-fired heater. It should have a metal pan made of sheet metal to sit in, for this will catch the oil if a leak occurs. A sandbox or cement must not be used as both the sand and cement will absorb oil and create a fire hazard.

13-37. Copper tubing is often used in an oil supply system because of its high resistance to corrosion and ease of installation. It is sold in rolls of 50 to 100 feet, from which appropriate pieces are cut. Flexible tubing sizes are often listed by outside diameter and wall thickness, instead of by inside diameter as in the case of iron pipe.

13-38. Copper tubing can be cut easily with a tubing cutter or a hacksaw. The cut ends must be reamed to remove the burrs or roughness that will restrict the flow of fuel. A major advantage of using copper tubing is that it can be easily bent without collapsing, especially when a tubing bender is used. By using copper tubing you reduce the number of fittings required, and there is less chance of leaks. Figure 33 shows the proper way to use a tubing bender.

13-39. Two ways of assembling copper tubing for a fuel supply system are first by flaring the end of the tubing and using flared fittings, as shown in figure 34, and second by using special ferrules and compression fittings such as are shown in figure 35. As you know, it is not necessary to cut threads on the tubing for either type of installation. When piping must be installed, you will use only black iron.

13-40. Since the correct flow of air to vaporizing-type oil burners depends primarily on the chimney draft, careful attention must be given to this feature. Poor draft results in a smoky flame that produces very little heat, while a downdraft makes it almost impossible to keep the flame going at all. An automatic type of damper is usually installed in the first joint of stovepipe at the point where the pipe leaves the heater. It is a weighted butterfly damper that maintains a constant draft, regardless of wind and temperature. For this reason, it is usually called a "draft regulator" instead of a damper. An illustration of a draft regulator is shown in figure 36.

13-41. The automatic and proper operation of a draft regulator depends upon correct installation, because it must be balanced correctly and be free to move at the slightest change in draft pressure.

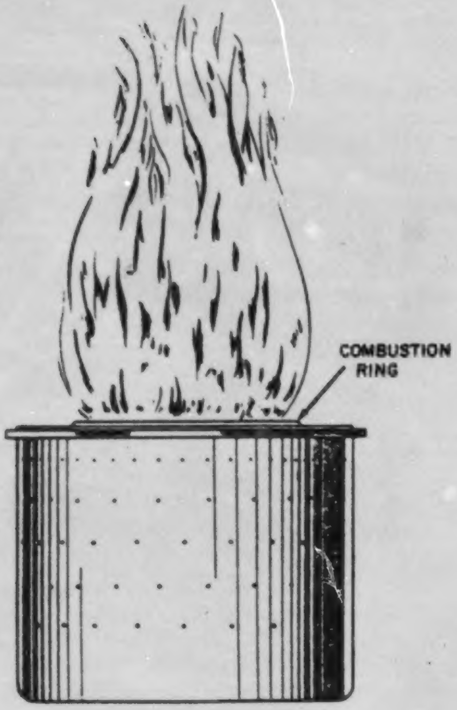


Figure 28. High-fire flame.

Regardless of whether the regulator is installed in a vertical, a horizontal, or an angled smokestack, the top of the damper must be at the true top position. The face must be plumb (straight up and down). When the regulator is used in a horizontal or nearly horizontal pipe, the counterweight is not used.

13-42. It is necessary for the heating specialist to know how to install flues and make repairs affecting draft in order for him to understand the factors affecting draft. All heating equipment should have a properly constructed chimney. The chimney should be made smoketight throughout, and should have the flue area and height that are in accordance with best engineering practices. Too many times the heating equipment is blamed when the fault lies entirely with draft conditions in the chimney. If the equipment is being installed in an existing structure, the chimney should be examined and reconditioned as necessary. A good chimney should be at least 25 feet high and of the approved size, with no sharp turns or abrupt offsets, and it should extend at least three feet above the highest point of the roof or any other structure or obstruction within 30 feet of it. When the wall that forms a chimney flue is made up of less than an eight-inch thickness of brick, concrete, or stone, a burned fire clay flue tile lining should be used. Care should be taken to see that the lengths of flue tile meet properly and have no openings at the joints.

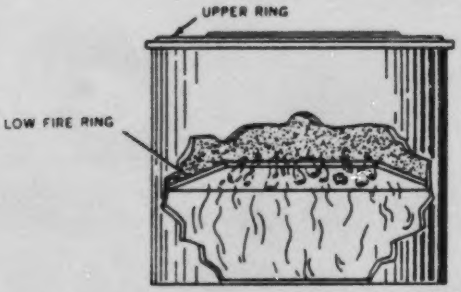


Figure 29. Low-fire flame.

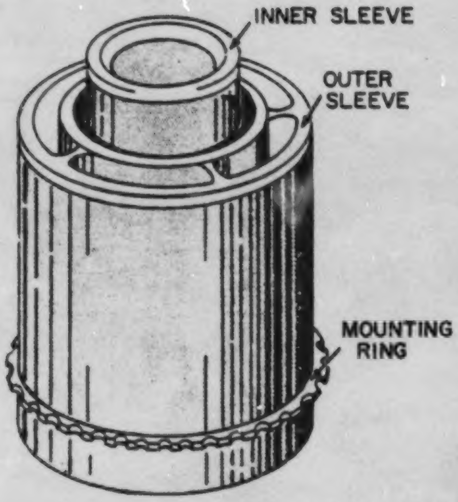


Figure 30. A sleeve-type distillate burner.

13-43. The draft in a chimney is created by the difference in weight between the hot air or gases inside the chimney, and the cold air on the outside. Hot air always rises; consequently, the hot gases produced by combustion will rise in the chimney and cause cold air to be drawn into the space heater to replace it. This continuous action of the hot air rising in the chimney, and being replaced by cold air drawn through the stove or space heater, is called "draft." In cold weather, the draft may be stronger, because of the much colder air outside the building; whereas in summer, the draft is less due to the smaller difference between the temperatures (and weight) outside the building and inside the chimney.

13-44. Knowing the principles on which a good draft depends, and assuming that the space heater

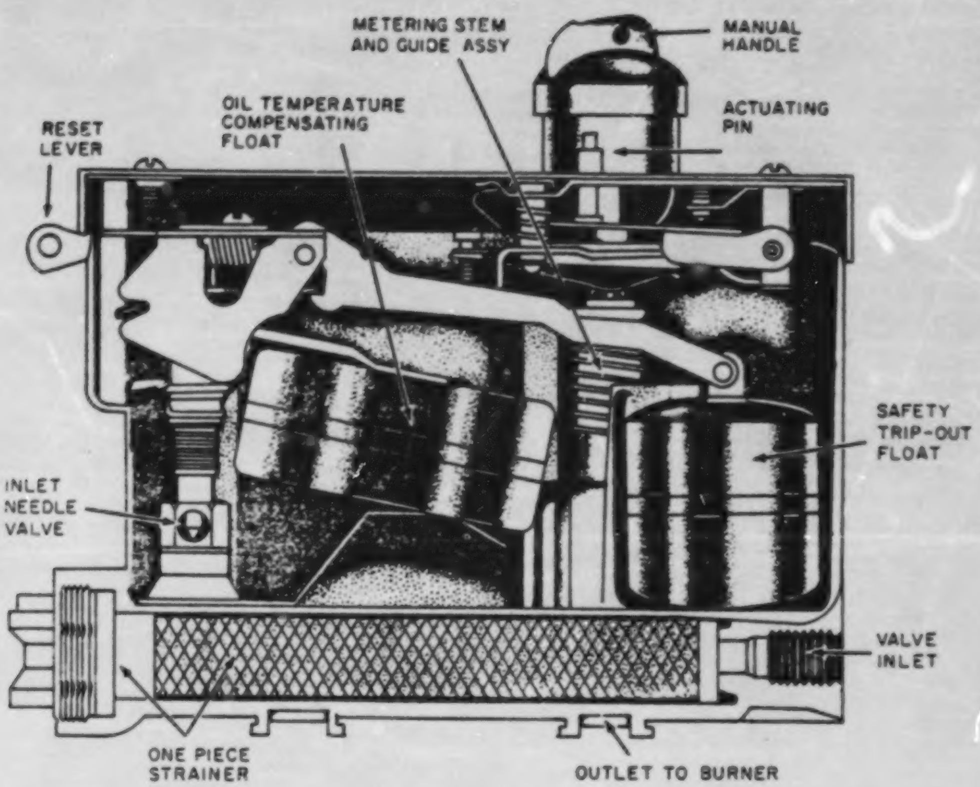

METERING STEM
AND GUIDE ASSY
MANUAL
HANDLE
OIL TEMPERATURE
COMPENSATING
FLOAT
ACTUATING
PIN
RESET
LEVER
SAFETY
TRIP-OUT
FLOAT
INLET
NEEDLE
VALVE
VALVE
INLET
ONE PIECE
STRAINER
OUTLET TO BURNER

Figure 31. Oil control metering valve.

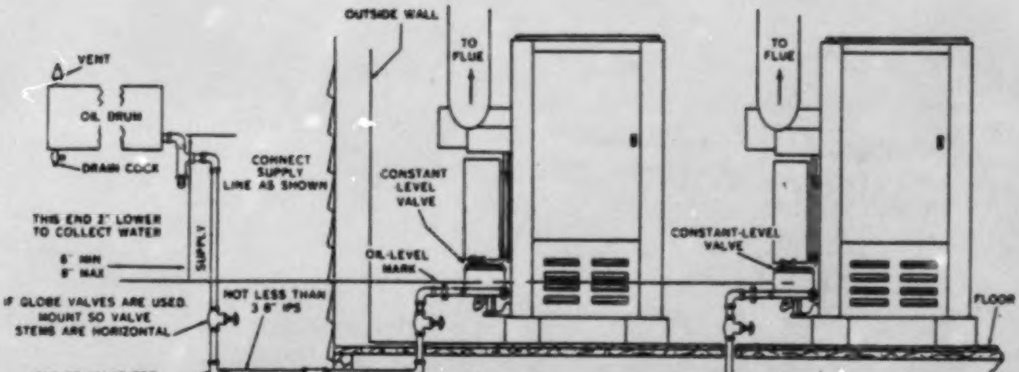

OUTSIDE WALL
TO
FLUE
TO
FLUE
VENT
OIL DRUM
DRAIN COCK
CONNECT
SUPPLY
LINE AS SHOWN
CONSTANT
LEVEL
VALVE
THIS END 2" LOWER
TO COLLECT WATER
SUPPLY
6" MIN
8" MAX
OIL-LEVEL
MARK
CONSTANT-LEVEL
VALVE
IF GLOBE VALVES ARE USED
MOUNT SO VALVE
STEMS ARE HORIZONTAL
NOT LESS THAN
3/8" IPS
FLOOR
CAP OR VALVE FOR
USE AS SEDIMENT DRAIN
TO OTHER HEATERS
MUST BE NO HIGH SPOTS IN LINE
HIGH SPOTS CAUSE AIR POCKETS

Figure 32. Space heaters installed in series.

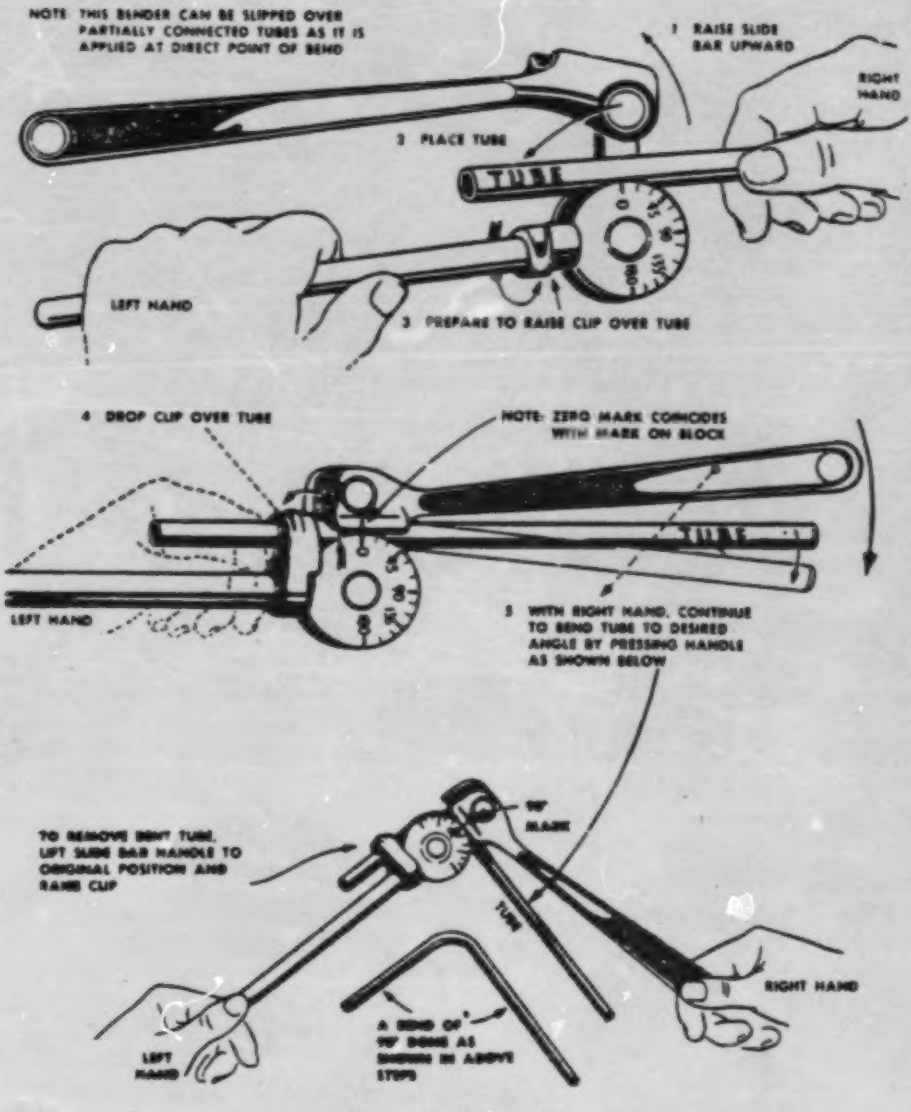

NOTE THIS BENDER CAN BE SLIPPED OVER PARTIALLY CONNECTED TUBES AS IT IS APPLIED AT DIRECT POINT OF BEND
1 RAISE SLIDE BAR UPWARD
RIGHT HAND
2 PLACE TUBE
TUBE
0
45
90
135
180
LEFT HAND
3 PREPARE TO RAISE CLIP OVER TUBE
4 DROP CLIP OVER TUBE
NOTE: ZERO MARK COINCIDES WITH MARK ON BLOCK
TUBE
LEFT HAND
5 WITH RIGHT HAND, CONTINUE TO BEND TUBE TO DESIRED ANGLE BY PRESSING HANDLE AS SHOWN BELOW
90° MARK
TO REMOVE BENT TUBE, LIFT SLIDE BAR HANDLE TO ORIGINAL POSITION AND RAISE CLIP
TUBE
RIGHT HAND
LEFT HAND
A BEND OF 90° DONE AS SHOWN IN ABOVE STEPS

Figure 33. Tube bending.

will be connected to a well-constructed chimney, you should observe the following when making the smokepipe connection. You should make the connection from the space heater to the chimney as short as possible. Install the smokepipe with an upward pitch of not less than one inch per running foot of length. You avoid sharp turns or other constructional features that will create excessive resistance to the flow of gases. Also, keep the smokepipe from entering beyond the inner wall of the chimney flue.

13-45. To be sure of doing good work when installing flues, the heating specialist must be able to recognize the common work faults, know how to correct them, and avoid making them. In another chapter we will discuss smokepipes and chimneys to a greater extent.

13-46. **Operating Oil-Fired Space Heaters.** When the oil control valve is opened, the oil enters the burner at the bottom of the pot and a torch is used to ignite it. As the oil begins to burn and vaporize, the vapors rise and mix the air entering through the perforations in the side of the pot. The position of the flame inside the burner depends on the amount of vapor produced. The amount of vapor produced depends on the oil level in the pot.

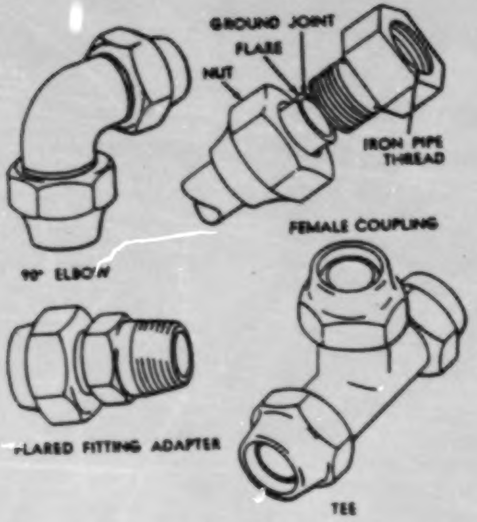


Figure 34. Flared fittings.

When large quantities of oil are being vaporized, the flame stands high on the top ring, as shown in figure 37, detail A. The vapor travels to this point before enough air is mixed with it to produce complete combustion at this high-firing rate. The medium-firing rate flame is shown in figure 37, detail B. The minimum or low-firing rate flame is as shown in figure 37, detail C.

13-47. Figure 37, detail D, shows the effect when the flow of oil into the pot is too slow. The vaporization and combustion take place at the bottom of the bowl. Air to support this combustion enters above the lower ring, so good mixing of the air and vapor is not possible and the flame is smoky. Under these conditions soot is deposited rapidly and fouls the heater and flue pipe so heavily that good operation is impossible. When combustion occurs below the lower ring, except during starting, the oil flow rate is insufficient. In this case, the oil-flow rate should be increased or the heater shut off entirely. If the flame stands too high above the burner or extends into the flue pipe, the rate of oil flow is too great. In this case, the rate of flow should be decreased to prevent dangerous overfiring.

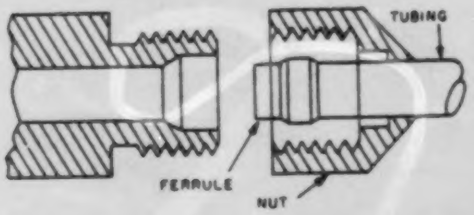


Figure 35. Compression fittings.

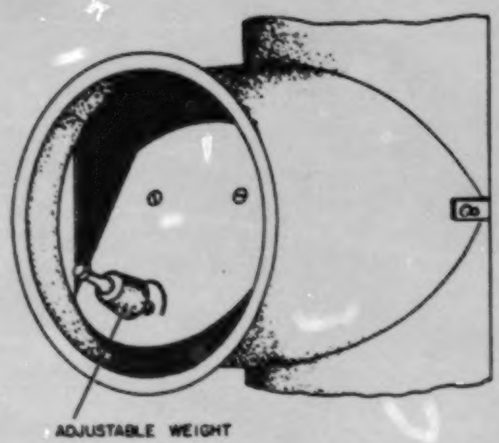


Figure 36. A typical draft regulator.

13-48. Maintaining Oil-Fired Space Heaters. Maintenance services should be accomplished in accordance with Army technical manuals, manufacturer's specifications, or local directives, to insure the proper operation of burners. Here are some of the common services that should be performed on pot- and sleeve-type space heaters during preventive maintenance.

13-49. You should remove the soot and carbon from the burners, heater exchangers, and chimneys. It is necessary to ream and clean out the oil inlet; also, to clean the oil storage tanks, the oil supply lines, and the strainers in the oil supply lines. You should lubricate the blower motors, clean the lighting pilot, and check all the electrical wiring on forced-draft oil burners. Also, clean and adjust the oil level control.

13-50. The oil level control valve, shown in figure 38, is an important part of the space heater, so it is necessary that it function properly. To obtain satisfactory results and uninterrupted service you should give regular attention to its periodic maintenance. The following suggestions are tips for doing this type of maintenance. You should avoid letting dirt or water accumulate on or in the valve; therefore, clean the screen regularly. Also avoid letting dirt or water mix with the oil. Make sure that the oil tanks are clean before they are filled. Do not use the valve assembly as a handle for lifting the heater. Before you service the oil level control valve, make sure that the oil supply is cut off.

13-51. The detailed procedures for accomplishing the maintenance that is required can be found in applicable technical literature covering the specific installation.

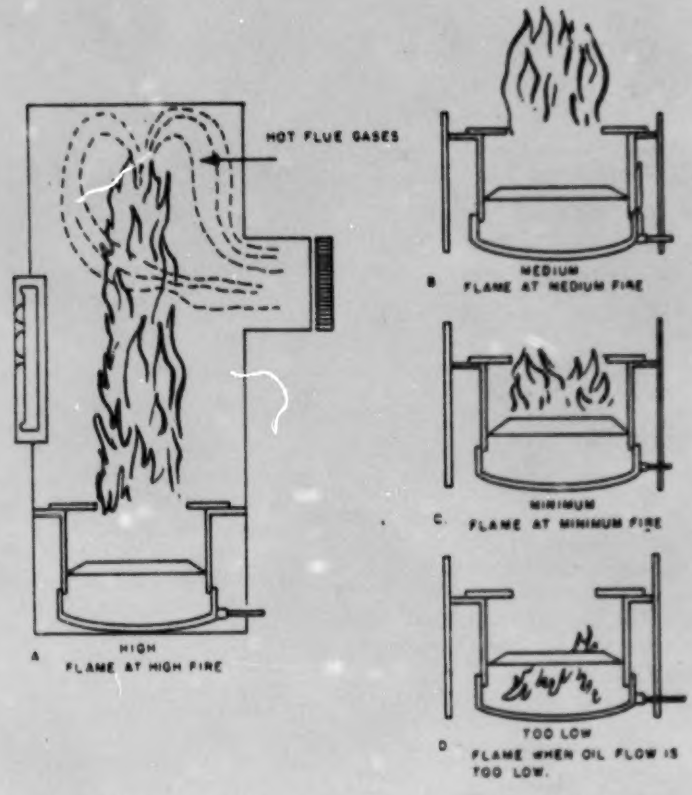


Figure 37. Position of burner flame at different rates of fuel flow.

13-52. **Troubleshooting Oil-Fired Space Heaters.** Some of the common causes of troubles encountered when troubleshooting pot- and sleeve-type oil-fired space heaters and their remedies are listed in chart 1.

CHART 1

Low Oil Flow

Probable Causes	*Remedies*
Air trapped in the oil supply lines. (This condition can be caused by a combination of air leaks and high points in the supply line.)	Eliminate the high points in the piping, correct leaks and bleed the line.
The oil control valve might not be level.	Level the valve.
The oil might be too heavy.	Use the grade of oil recommended by the manufacturer.
Dirt in the oil supply line.	Clean the supply line.
Dirt in the metering mechanism.	Clean the metering mechanism.
A clogged oil strainer.	Clean the strainer.
Sludge clogging the supply line.	Clean the supply line.
The fuel inlet clogged with carbon.	Remove the carbon.

Burner Smokes

Probable Causes	*Remedies*
Improper fuel.	Use the grade of fuel recommended by the manufacturer.
Insufficient oil flow.	Troubleshoot for low oil flow.
Excess chimney draft.	Check the draft regulator for proper operation.
Pilot casing is poorly fitted to the casing.	Remove and install the pilot casing properly.
The burner needs cleaning.	Clean the burner.
Excessive flue downdraft.	Modify the chimney height as required, or install a downdraft hood.

Burner Goes Out

Probable Causes	*Remedies*
Low oil supply.	Add oil if necessary.
Plugged vent on the oil supply tank.	Clean the vent.
Insufficient oil flow.	Troubleshoot for low oil flow.
Improper fuel.	Use fuel recommended by the manufacturer.
Fuel inlet plugged with carbon.	Clean the fuel inlet.
Dirt in the oil control valve.	Clean the valve.
Oil valve is not level.	Level the valve.

Probable Causes	*Remedies*
Filter cartridge is plugged with sludge and dirt.	Clean the filter.
Excessive chimney draft.	Check for proper operation of the draft regulator.
Excessive flue downdraft.	Modify the chimney height as required, and install a downdraft hood.

Burner Flooded

Probable Causes	*Remedies*
Dirty float valve.	Remove and clean the float valve.
Improper operation.	Instruct operating personnel on the proper procedures of operation.
Needle valve stuck.	Clean or replace the needle valve.

High Fuel Consumption

Probable Causes	*Remedies*
Improper fuel.	Use fuel recommended by the manufacturer.
Heat loss.	Reduce the supply of air to the burner.
Heat exchanger areas caked with carbon and slag.	Clean the caked areas.
Excessive chimney draft.	Check the operations of the draft regulator.

13-53. **Types of Gas-Fired Space Heaters.** Gas-fired space heaters can be used to satisfy specific heating requirements wherever gas is available. Space heaters are clean in operation, they are easily operated, and require no fuel handling. Natural, manufactured, or liquefied petroleum (L. P.) gases can be burned in these units.

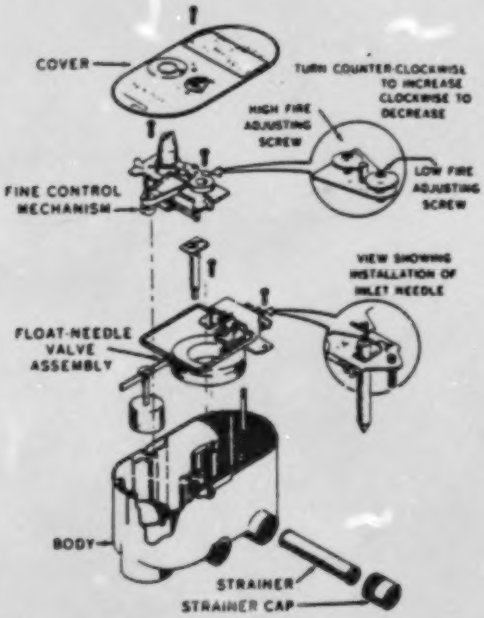

COVER
TURN COUNTER-CLOCKWISE TO INCREASE CLOCKWISE TO DECREASE
HIGH FIRE ADJUSTING SCREW
LOW FIRE ADJUSTING SCREW
FINE CONTROL MECHANISM
VIEW SHOWING INSTALLATION OF INLET NEEDLE
FLOAT-NEEDLE VALVE ASSEMBLY
BODY
STRAINER
STRAINER CAP

Figure 38. An exploded view of an oil control metering valve.

13-54. Natural gas and manufactured gas are lighter than air. In case of a leak, they rise and drift away without much danger. However, liquefied petroleum gas, such as butane and propane, is heavier than air and collects in low spots and remains there. This condition can easily result in a fire caused by sparks or carelessly discarded matches. For this reason, the leakage of L.P. gas must be carefully avoided.

13-55. Gas-fired space heaters, using any of the gases mentioned, are of similar construction. They may be vented or unvented; that is, they may or may not be equipped with a pipe to carry away the flue gases.

13-56. *Unvented gas space heaters.* Unvented gas space heaters are usually of the open-flame type, in which the gas burns in an open combustion chamber. These heaters should be used only in well-ventilated places so as to gradually remove the carbon monoxide and other gases produced by the gas flame.

13-57. *Vented gas space heaters.* The vented gas space heaters are of the inclosed type. They consist of a steel cabinet provided with top and bottom grilles or openings to facilitate the circulation of warm air. The flame burns in a closed combustion chamber, and the gases are carried away by the heater vent which is connected to the pipe. Space heaters of the vented type are more satisfactory than the unvented type, because there is less danger of carbon monoxide poisoning. A typical floor-type vented gas space heater is shown in figure 39.

13-58. **Installing Gas-Fired Space Heaters.** All gas-fired space heaters and their connections must be of the type approved by the American Gas Association (AGA), and they must be installed in accordance with the recommendations of the AGA.

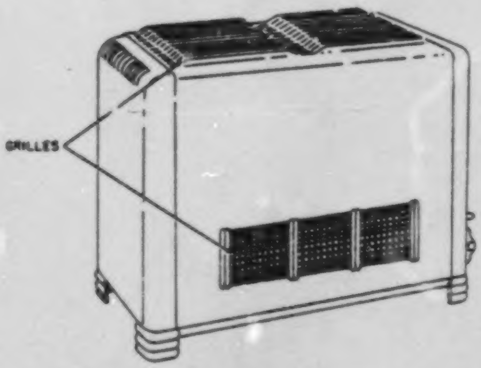


Figure 39. A typical floor-type vented gas space heater.

13-59. The gas line used to convey natural or manufactured gas to the space heater is usually black iron pipe. The size of the pipe used depends partially upon the maximum gas consumption of the heater (AGA name plate rating), length of pipe, and the number of fittings. The size also depends upon the allowable loss of pressure from the building entry to the space heater. The pipe size used also depends upon the specific gravity of the gas. Capacity tables showing the flow of gas in pipes, in cubic feet per hour, with the various pressure drops are available in many handbooks.

13-60. Before pipe joints are assembled, all pipe ends are reamed and pipe dope placed only on the male threads. After the piping is assembled, it should be fastened securely to prevent vibration. After the gas is allowed to flow into the new piping, care should be taken to test all of the pipe joints with a soap and water solution. A match could cause an explosion.

13-61. Care should be taken to properly install the venting system for gas-fired space heaters, minimize the harmful effects of condensation, and insure that the combustion products are carried away by the pipe. Approximately 12 gallons of water are produced by burning 1,000 cubic feet of natural gas. The inner surface of the vent must, therefore, be heated above the dew point of the combustion products to prevent water from forming in the flue pipes. You install the vents with the male ends of the inner liner down, to return condensation within the pipe on a cold start. Horizontal flue pipes should have an upward pitch of at least one inch per running foot.

13-62. Vents for combustible framing must be installed according to pertinent local and Army regulations. You construct the vents of material that is resistant to the corrosion caused by flue gas products, and install the same size vent pipe throughout the entire venting system. A vent should never be made smaller than the heater outlet.

13-63. Each gas-fired space heater should be equipped with a draft diverter or hood, such as that shown in figure 40. The diverter is a type of inverted cone through which the flue gases must pass on their way to the chimney. The cone also allows air from the heater room to be drawn into the flue pipe along with the flue gases. The purpose of the draft diverter is to prevent the chimney from producing an excessive updraft or downdraft condition. Either condition is apt to extinguish the pilot light or the main burner flame.

13-64. After a new installation has been hooked up, it is necessary to check the equipment or operation and make adjustments. On these new installations, you should bleed the air from the gas piping. You also close the main gas valve on the heater and pilot cock to prevent filling the combustion chamber with gas. Then you disconnect the pilot tubing outside the heater and open the valve supplying gas to the system so that the air will be expelled through the pilot line. When all air has been removed from the system, you reconnect the pilot line. You should follow the proper sequence of this procedure to avoid accidents.

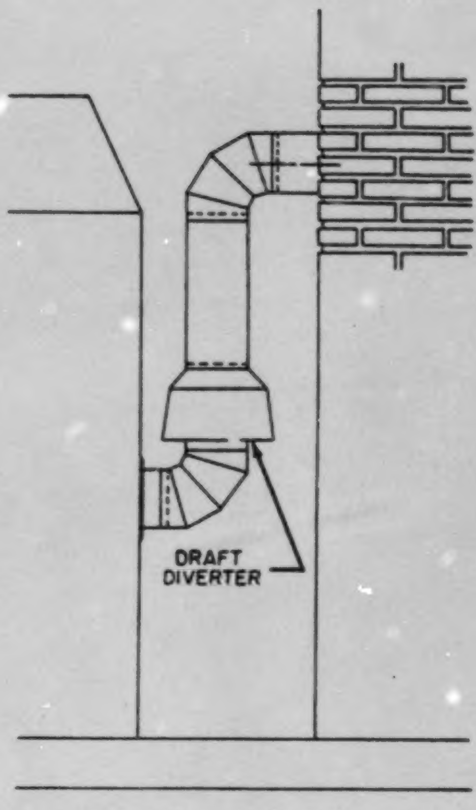


Figure 40. A typical draft diverter.

13-65. When you adjust the gas flame, you close the airmixer for the main burner until the flame is yellow, then you open the shutter on the airmixer until the yellow disappears. Insufficient amounts of primary air cause the flame to burn yellow and result in sooting of the unit when the flame strikes the heating unit. Too much primary air causes inefficient operation, and this will sometimes cause the flame to pop back into the airmixer. This results in a yellow flame at the burner head.

13-66. Most of the gas-fired space heaters used by the military are manually controlled. A pilot light is usually provided, and the heat is turned on or off by a hand-operated valve. When a pilot light

goes out, the escaping lighter-than-air gas (natural or manufactured) rises through the vent and dissipates into the atmosphere. Heavier-than-air gas (liquefied petroleum) accumulates in the surrounding space and produces health and fire hazards. For this reason 100-percent shutoff thermostatic pilots are required on space heaters using liquefied petroleum gas. The term "100-percent shutoff" means that the gas flow through the pilot, as well as through the main burner, is shut off automatically when the pilot light is extinguished. The 100-percent shutoff is operated by a thermocouple operating a cutoff valve.

13-67. **Maintaining Gas-Fired Space Heaters.** Gas-fired space heaters should be inspected and maintained according to a schedule prescribed by Army Regulations or local directives. The chimney and pipe should be examined from the outside as well as the inside of the building. Any noticeable deterioration such as rusting, broken guy wires, and the like, should be reported.

13-68. It is necessary to take off the casing and pipe and remove the gas burner from a heater to clean soot from the heater. Some elements can be cleaned by simply tapping them with a piece of wood to loosen the soot. The soot can then be removed by running the flexible suction hose from a vacuum cleaner through the unit. When you use air pressure to blow out the soot, you should first move the heater out of the building.

13-69. Burners and heating elements will soot up when foreign matter gets into the venturi tube and interferes with the proper flow of gas and air. This causes the flame to burn yellow. To correct this difficulty, you must take out the venturi tube and burner head, and remove the obstruction.

13-70. Usually, a yellow flame is caused by insufficient primary air. Perhaps this is due to improper adjustment at the airmixer, or to lint or other matter being lodged against the opening around the airmixer. You simply adjust or clean the airmixer to remedy these difficulties. The venturi or burner that is clogged with cooking oil and fats is cleaned with boiling water.

47

CHAPTER 4

Coal-Fired Furnaces and Stokers

IN THE PAST, when people heard the term "heating specialist," they automatically thought of a wheelbarrow, a shovel, and a dirty fireman. Today, however, the art of operating coal-fired heating equipment has become a much easier and cleaner job because of the invention and use of automatic stokers. You will notice that in this chapter we mention boilers as well as furnaces in connection with stokers. However, boilers will be discussed in Memorandum 567.

2. The fuel-burning or heat-liberating equipment consists of the furnace and the machinery for introducing fuel or a fuel-air mixture into the furnace. Coal can be fired by hand, by stokers, or by pulverizing it to a very fine powder and blowing it into the furnace under low pressure. When coal is fired by hand or stoker, the coal fumes and air are mixed in the furnace. When pulverized coal is used, most of the air needed for combustion is mixed in as the coal enters the furnace. In Chapter 3 we discussed coal-fired space heaters and space heating. In this chapter we will be discussing the construction, operation, and maintenance of coal-fired furnaces and stokers.

14. Hand-Fired Coal Furnaces

14-1. Although hand-fired coal furnaces are slowly being phased out of the heating equipment inventory of the military, either by replacement or conversion to gas or oil, there are still a number of these furnaces in use in areas where coal is less expensive and readily available. As a heating systems specialist, you must be familiar with these types of heating units. You never know when you will be called upon to operate, maintain, and repair hand-fired coal units. Warm-air furnaces are made of either cast iron or sheet steel. The sheet steel furnace can be used for either gravity or forced-air heating. The cast iron furnace, however, is used only for gravity heating. The cast iron furnace is probably the better known of the two units and is the type which we will discuss first.

14-2. **Cast Iron Furnaces.** The cast iron furnace is generally used for gravity heating in small buildings, and is an older type than the sheet steel furnace. The major parts of the cast iron furnace are the ashpit, firepot, combustion chamber, radiator, grates, firedoor, hood, and water pan. The furnace is constructed of cast iron about three-eighths of an inch thick. This makes the furnace heavy and sturdy, so that with proper care it will give years of satisfactory service.

14-3. The cast iron furnace is made in sections; consequently some method must be used to prevent leakage of gases between the sections. The edge of each section is grooved to fit the one above, and a fireproof cement (asbestos rope) is put in the groove before the furnace is assembled. There will be no leakage at the joints of your installations if you properly apply the cement.

14-4. *Grates.* The grates are used to support the burning coals, and they are located in the top of the ashpit section, as illustrated in figure 41. The grates can be bolted in place or fitted into grooves. Figure 42 shows the circular bar (duplex) grate. The circular section of the grate rests on either balls or rollers and rotates about one-third of the distance around the ashpit, causing the ashes and clinkers to fall to the center. There are usually three or four of these rollers. The center portion of the grates consist of two sections that open and close to dump the ashes and clinkers into the ashpit.

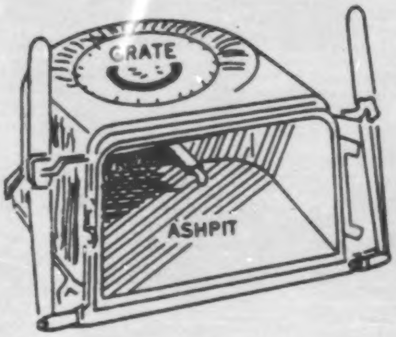


Figure 41. Ashpit grate assembly.

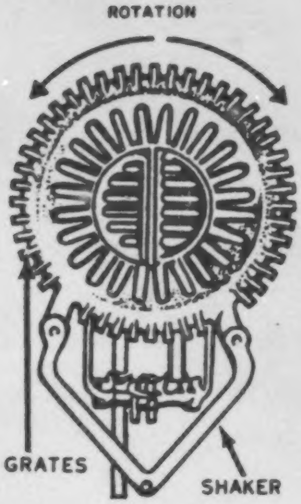


Figure 42. Circular duplex grates.

14-5. Another form of grate is the bar type, shown in figure 43, which is composed of four movable bars with interweaving fingers. These grates can be either rectangular or flat-shaped units.

14-6. *Firepots.* A thick, heat-resistant chamber must be provided to hold the burning fuel without its being damaged by the high heat of the fuel bed. The cast iron firepots located directly above the ashpit serve this purpose.

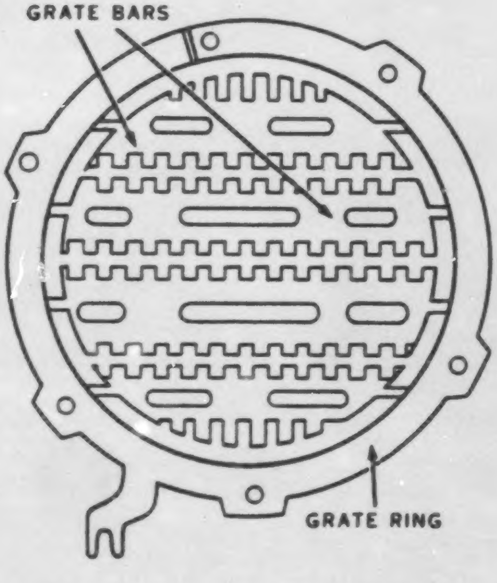


Figure 43. Typical bar grate.

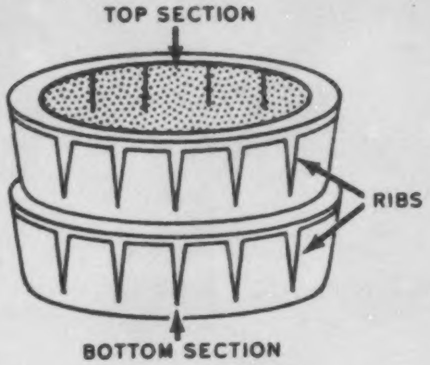


Figure 44. A two-section firepot.

14-7. Firepots generally come in two pieces, the upper pot and lower pot. A two-section firepot is shown in figure 44. The ribs on the inside and outside give strength and long life. These types of firepots are used in cast iron furnaces only.

14-8. *Combustion chamber.* The combustion chamber is a very important part of the furnace. This section is located directly above the firepot, and it serves two purposes. The gases driven from the fuel burn here, and new fuel is added through a door located in the front of the feed section.

14-9. *Radiators.* Better heat transfer and, consequently, greater efficiency are obtained by having a long path for the flue gases to travel in the furnace before reaching the flue. Therefore, a radiator is installed between the combustion chamber and the flue to obtain this longer path for the hot gases. The radiator is a large circular casting which sits on top of the feed section. The burned gases circulate through it on their way out to the smokestack, and thus give up more heat. Radiators may be of one-piece or two-piece construction.

14-10. Two-piece radiators have a cemented and bolted joint that continues down the entire length of the radiator. The cement makes a tightly-sealed joint, and the bolts hold the halves firmly in place.

14-11. The one-piece radiator provides a more dustproof, gastight and airtight assembly. One opening in the radiator is the cleanout, while the other open end is the smokepipe. On many furnaces the radiator can be turned to any position. This is to simplify the connection made between the smoke outlet and the chimney. The length of the smokepipe must be kept as short as possible. Many steel furnaces use a radiator constructed of riveted sheet steel. The radiator is fastened vertically to the rear of the combustion chamber, and the smokepipe connection is at the lower end of the unit.

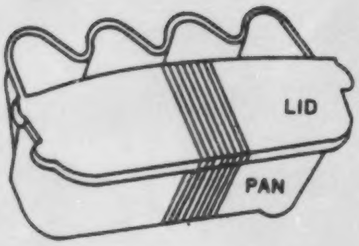


Figure 45. A typical water pan.

14-12. *Water pan.* Water pans, such as the one shown in figure 45, are sometimes used as humidifiers to add moisture to the air. When the proper percentage of humidity is maintained, it is possible to be comfortable at lower temperatures.

14-13. *Liner.* Two sheet metal cylinders are installed, one inside the other, around the firepot and radiator. The inner cylinder is the liner. The air between the firepot, radiators, and the liner is heated and conducted to the areas requiring heat. Between the liner and the outer casing is a dead air space. The purpose of this dead air space is to reduce the heat losses through the outer casing. This is accomplished by the dead air space acting as an insulator.

14-14. *Bonnets.* A typical bonnet or hood that is used with a gravity warm-air furnace is shown in figure 46. The top of this bonnet is shaped like a cone so that the air is guided into the hot-air outlets located around the side of the bonnet. The cone is usually filled with sand to prevent any heat loss through the bonnet as the warm air comes in contact with the top of the hood. The bonnet is insulated, not only to conserve heat, but to eliminate the possibility of fire hazards. The sand is sometimes covered with a thin layer of cement mortar to provide a smooth surface for easy cleaning.

14-15. In the preceding paragraphs we have been discussing cast iron furnaces and their component parts. In the following paragraphs we will discuss steel furnaces and their construction.

14-16. **Steel Furnaces.** The type of steel furnace shown in figure 47 has become popular in recent years because it has some advantages over the cast iron furnace. One good feature is that its installation cost is lower. It also has fewer joints, and there is less chance for gas and soot leaks. The steel furnace can be set up easily in a short period of time because it is much lighter than the cast iron furnace.

14-17. The main part of the steel furnace is the combustion chamber around which the air passes as it is heated by the fire on the inside. It is here that combustion of the fuel takes place. The fuel burns in the brick firepot, and the gases burn in the upper section. Heat is absorbed by the walls of the combustion chamber and transferred to the circulating air by means of convection and radiation.

14-18. As with the cast iron furnace, the grates are used to support the burning coal. They also provide for an air space below the fuel bed. The grates fit into the bottom of the heating element, and they sit on a grate ring bolted to the combustion chamber. The grates are usually of the bar type. They have an upright shaker handle that allows easy shaking to remove ashes from the fire.

14-19. The type of radiator shown in figure 48 is used in steel furnaces to add heating surface and increase the travel of the flue gases. The V-type baffle in the radiator is located just below the collar that connects the radiator to the combustion chamber. Hot gases from the fire are deflected and spread by these baffles, so that the entire radiator is heated uniformly before the gases pass into the smokepipe.

14-20. The casing for a steel furnace is almost like the one for a cast iron furnace, except that the smokepipe opening is located in the lower part of the casing. Steel furnaces may have square casings instead of round ones.

14-21. Most steel furnaces are lined with firebrick to prevent the flames from burning through

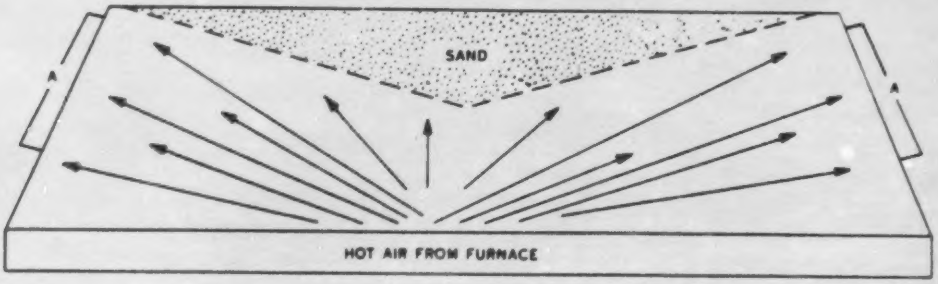


Figure 46. A typical bonnet for gravity warm-air furnace.

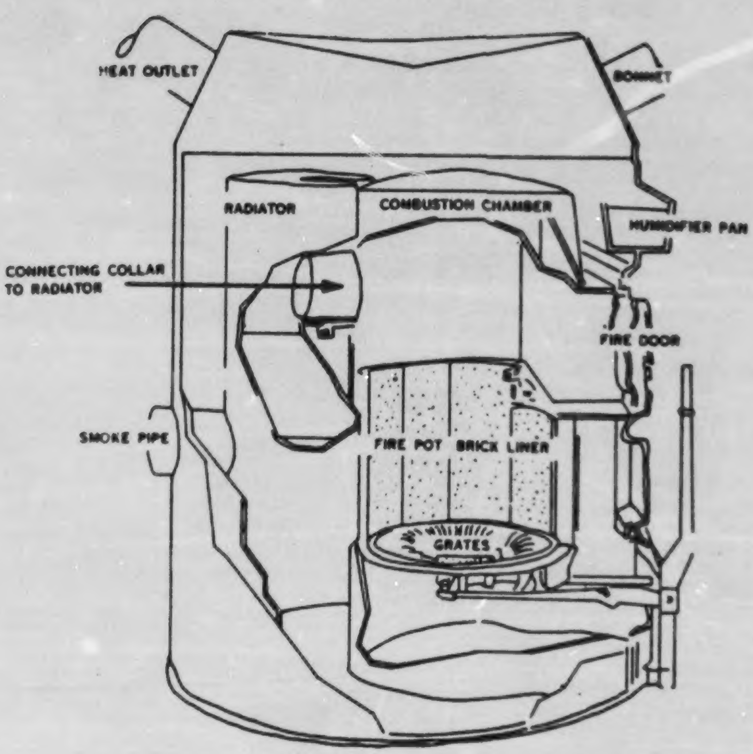


Figure 47. A steel furnace.

the thin metal during operation. This installation is called the "refractory." The bricks also help absorb and deaden the sound of combustion. Figure 49 shows a combustion chamber that has a refractory. The lower row of bricks is held in place by the wedge-shaped edges of each brick. The upper row of bricks is held in place by adjustable, bolted clamps. The lower bricks are protected from shovel damage by a steel or cast iron plate installed at the bottom of the firing door.

14-22. When the firedoor of a downdraft furnace is opened for firing, smoke often rolls out of the door into the fireman's face and into the room. This condition is overcome by installing a direct-draft damper in the radiator and connecting it to the fire door with a chain or rod. Figure 50 shows a direct-draft damper installation.

14-23. When the firedoor is opened, the direct-draft damper is also opened. This action creates draft, and the burning gases pass directly to the chimney instead of coming out through the firedoor.

14-24. A blower is used when the heating installation is large or there is need for close control of the amount of heat delivered. A typical blower unit is illustrated in figure 51. The blower sits on a steel base fastened to the floor. The fan is often the squirrel-cage type, although the blade-type blower is used on many installations. The blower housing forms a duct or air passage for drawing air into the duct and forcing it into the furnace. Here the air is heated and forced out through the warm air ducts to the building. The fan is driven by an electric motor that has an adjustable speed pulley. This pulley drives the V-belt that is connected to the fan pulley.

14-25. You can adjust the fan belt by loosening the motor base bolts and moving the motor to place a sufficient amount of tension on the fan belt. You should avoid placing too much tension on the belt, because this places an unnecessary strain on the bearings and causes excessive wear on the motor, the fan, and the shaft. The correct amount of tension can be determined by pushing in on the fan belt midway between the two pulleys. Between three-quarters of an inch and one inch of depression of the belt is correct for most fan belts. The belts should not be operated loose as slippage will cause excessive belt wear and quickly ruin the belt.

14-26. When a blower is used, one or more filters, as shown in figure 52, are normally installed

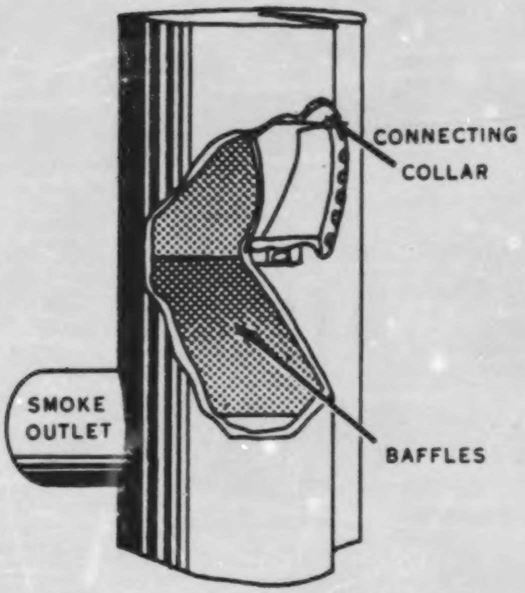

CONNECTING
COLLAR
SMOKE
OUTLET
BAFFLES

Figure 48. A steel radiator.

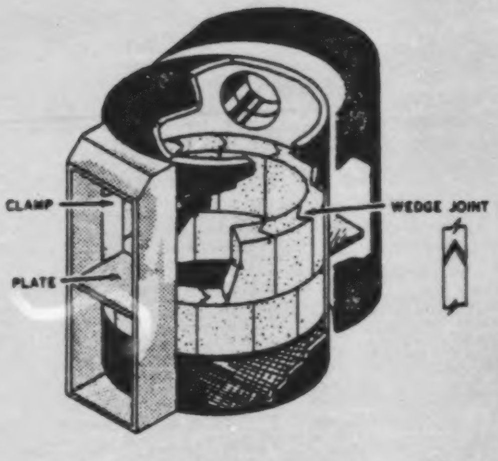

CLAMP
PLATE
WEDGE JOINT

Figure 49. A combustion chamber with a refractory.

to clean the circulating air. These filters are placed so that all of the air going through the furnace is drawn through the filters by the blower.

14-27. Heavy-duty furnaces and blowers are used for large buildings. These furnaces and blowers are similar in construction to the smaller furnaces and blowers, except that they are larger. Figure 53 shows a heavy-duty furnace that has two radiators. This furnace has a capacity of one million Btu at the bonnet. This type of furnace is used with forced air only.

14-28. **Firing Warm-Air Furnaces.** Several firing methods are advocated for warm-air furnaces. The spreading method requires continuous

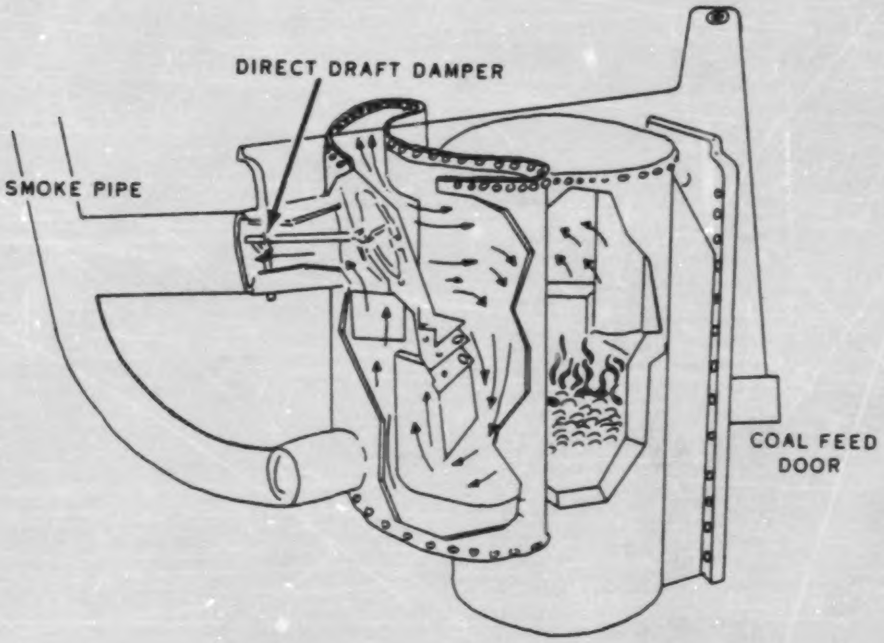

DIRECT DRAFT DAMPER
SMOKE PIPE
COAL FEED
DOOR

Figure 50. A direct-draft damper installation.

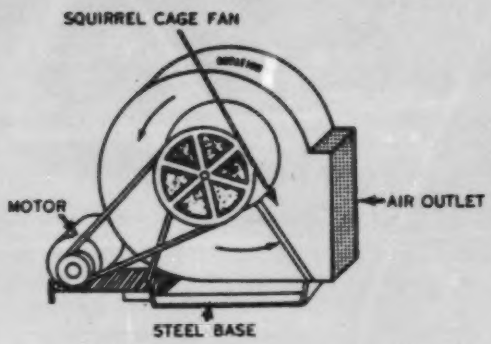


Figure 51. A typical blower unit.

attention and can be used successfully only by an expert fireman. The other methods back-to-front, front-to-back, side-to-side, center-to-cone, rim, or locomotive methods are really adaptations of one basic method. All of these methods will give excellent results when they are carefully followed by all work shifts. For uniformity and simplicity of instruction, and for best results with temporary firemen, the back-to-front method is preferable for anthracite firing, while the front-to-back method is preferable for bituminous firing.

14-29. The proper operation of any heating unit is important if you are to obtain the maximum efficiency. Improperly firing a furnace can result in damage to the furnace, the lack of heat, and the waste of coal.

CAUTION: Oil or gasoline must never be used to start a coal fire. Many people have lost their lives by explosions caused by pouring these volatile fuels on coal.

14-30. The grates should be completely free of ashes and clinkers when you are starting a fire in a coal furnace. The best way to start a fire is with paper and kindling wood. The smokepipe damper must be opened to allow a full draft to the furnace, and the draft door should be kept closed until the wood starts burning. Then, only a thin layer of coal is added, since too much coal will

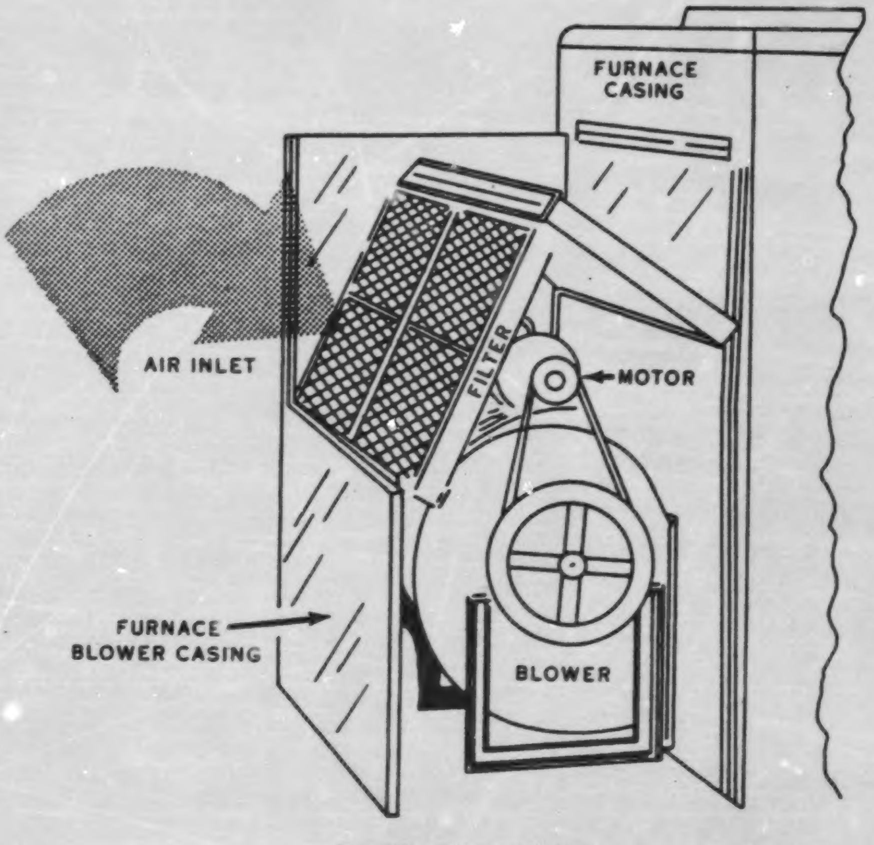


Figure 52. Filter installation.

53

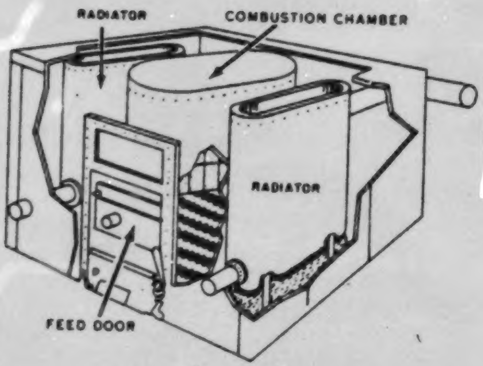


Figure 53. Heavy-duty furnace with two radiators.

smother the fire and form gas. When this gas becomes ignited, it "explodes" and often blows the furnace doors open.

14-31. The draft door must be shut to prevent overheating the furnace once the fire has started. After the furnace is in operation, all that is necessary to do is keep enough fuel on the fire and prevent the ashes from piling up under the grates. If a hand-filled water pan is used on the furnace, care must be taken not to allow the water to overflow, because water on the hot metal will cause it to crack or warp.

14-32. Most hand-fired furnaces have the draft and damper joined by a chain, and they operate together. When the draft is not controlled by a thermostat, the operator has to control the fire manually by adjusting the draft.

14-33. A furnace should be fired lightly, evenly, and frequently to obtain best efficiency. The maximum amount of heat is obtained when the entire surface of the grates is covered with burning coal and only a small amount of ash separates the grates from the coal. This allows the most air to get to the burning coals and increases the rate of combustion. A light layer of burning coals is preferred to a heavy layer of unburned coal. This condition allows the air to flow freely through the coals, mixing with the burning gases. It increases the speed with which the fuel burns. Also, having more air, more coal is burned, consequently resulting in less ash and fewer clinkers.

14-34. You can tell when you have a good fire by observing the color of the burning coals. Dark spots in the fire usually indicate either a bare spot where there is no coal, or just ashes, or a pile of unburned coal. Neither condition produces any heat. When you have a good clean fire, the ashpit is evenly lighted, and no shadows or dark spots are visible. If the furnace is being properly fired, very little shaking of the grates is necessary, since the coal burns down to a fine ash and drops down through the grates by itself.

14-35. Putting a large quantity of coal at one time in the firebox, or overfiring in order to reduce the frequency of feeding the furnace, is wasteful and dangerous. Overloading the furnace can cause the firebox to fill up with unburned gases which ignite and explode.

14-36. Frequently heat is not required, but still the fire must be maintained. This situation is solved by banking the fire. Banking the fire in a large furnace or boiler is done by placing a pile of coal in the rear half of the furnace and none in the remaining front half. The draft door, damper, and fire door are left open just a little, allowing just enough air to circulate through the fire to keep it from going out. When heat is again needed, the pile of coal is spread out over the entire firebox with a hoe. The damper and the fire doors are closed, and the draft door is opened until an even fire covers the grates. When you bank a fire in a home furnace, pile the fresh coal in the center of the firepot with the outer edges free of fresh coal. The fire is best maintained by the coal burning at the edge of the pile.

14-37. During normal firing, you should keep the ashpit door closed and regulate the amount of air by opening and closing the draft door, except when starting a fire. At starting time the ashpit door is left open until the coal is burning; then the door is closed.

14-38. In the preceding paragraphs you have learned about the operation of coal-fired furnaces; in those that follow you will study about maintenance of these furnaces.

14-39. **Maintaining Warm-Air Furnaces.** An inspection should be made at the end of each heating season, at which time all necessary maintenance should be accomplished and repairs made. The warm-air furnace normally needs very little maintenance.

14-40. A furnace must be kept clean, because soot is a very good insulator of heat and is a fire hazard. The chimney cleanout, smokepipe, and firebox surfaces must be kept cleaned out. In case of heavy firing, it will be necessary to clean these places more often.

14-41. The major units that require replacement are the smokepipe, grates, and combustion chamber. If a rusted smokepipe contains small pinholes, it should be replaced; otherwise, the holes quickly become larger and create a fire hazard.

14-42. Grates will give many years of service if they are properly cared for, but when abused they can burn out overnight. When the ashes are allowed to collect in the ashpit, they cut off the circulation of air beneath the grates. When you shake the grates, a certain amount of hot ash or coal usually shakes through. This in effect is like putting the grates in the middle of the fuel bed. Consequently, the grates become burned and do not function properly.

14-43. Grate failure can also be caused by leaving the grates uneven. After you finish shaking the grates, the top of the bars should be left level; otherwise, the fingers on one side will stick into the fuel bed with the other side in the cooler ashpit. This condition causes the grate bars to warp and burn. When a single grate bar becomes disconnected, it can be damaged in the same manner.

14-44. Another cause of failure of the grate bars is excessive "banking." In banking, a large amount of fuel is added to carry the fire over a long period of time between firings. This increases the resistance to the passage of air through the fuel bed. Also, when banking, it is common practice to close the draft door to cut down on the rate of burning coal. This results in more heat traveling from the fuel bed to the grate bars, which can cause them to become overheated. When the draft is partially cut down by closing the damper in the smokepipe, the chance of wraping or burning the grates is also increased, because of the smaller amount of air passing through them. It is important to allow air to pass through the grates to cool them. However, if the drafts are to be closed, a thin blanket of ash should be left on top of the grates to protect them from the fire.

14-45. Grates can be easily replaced by removing the bars, pins, and any bolts that hold them in place. The grate can then be removed through the door frames and be replaced by new ones.

14-46. In the steel furnace, the firebrick in the combustion chamber can be damaged by striking the brick with the poker while you are removing clinkers from the firebox. The brick clamps must be loosened to remove an upper brick, then the damaged brick is replaced with a new brick. When replacing a lower brick, it is necessary to remove some of the upper bricks.

14-47. When replacing a single brick, it is often necessary to chip the replacement brick to the proper size. This is done by marking the brick and tapping it evenly with a chisel. If a brick is too small, it must be wedged in tightly and the open places sealed with fire cement mortar.

14-48. You should replace the air filters at least once a year. When a filter becomes dirty, it slows the flow of air and does not provide the proper filtering. The arrows on the filters show you the direction of air flow for correct installation.

14-49. The blower should be oiled three or four times each year. The blower shaft usually has oil cups that should be filled, but the electric motor requires only three or four drops of oil. *You should be careful not to overoil* the motor, because excessive oil will run out of the bearings and saturate the windings. The manufacturer's directions for oiling should be followed.

14-50. We have been discussing the types, construction, and components of coal-fired furnaces. We have also covered hand-firing of these furnaces. The methods of hand-firing coal-fired boilers are basically the same as those for furnaces. The grates used in small hot water and steam coal-fired boilers are similar to those used in warm-air furnaces. You will find, however, that the grates of larger boilers and their conventional methods of being fired do differ from those of the smaller units, depending upon the type of stoker used. In this next section we will discuss these stokers and grates and their controls.

15. Automatic Stokers

15-1. Most coal-burning central heating plants and many barracks' units are equipped with stokers. The stokers have several advantages over hand firing: (1) They permit the use of cheaper grades of fuel, such as slack and mine-run coal; (2) there is better furnace and boiler maintenance because of better combustion; (3) labor is reduced because there is less handling of coal; and (4) there is an increase in the output capacity of the plant.

15-2. In the early stages of small stoker development, various methods of feeding coal from the reservoir or hopper to the area where it was to be burned were developed and tried. Many mechanical devices were used for moving coal to the fire. Some of these methods worked very well for large industrial plants, but they were inefficient in operation for the smaller units. In the following paragraphs we will discuss these types of stokers.

15-3. **Types of Automatic Stokers.** Four basic types of automatic stokers have been developed. These are underfeed, spreader, traveling or chain grate, and overfeed stokers. Each type of stoker has its own field or use, depending largely upon the fuel used.

15-4. *Underfeed Stokers.* Underfeed stokers received their name from the fact that fresh fuel is supplied below the burning zone. When firing with an underfeed stoker, there are three zones which exist in the fuel bed. They are: Fresh or green (on the bottom), the coking zone (in the middle), and the incandescent or burning zone (at the top). Fresh coal enters at the bottom of one end and is distributed over the entire retort, and it is forced to move gradually to the top where it burns. As the coal travels up from the bottom of the retort, the temperature gradually rises; this causes gaseous matter to be given off, and it mixes with the air supply and passes up through the hotter zones of the fuelbed. As the temperature of the gases and of the air rises, the mixture ignites and burns. The mixture may burn just below the surface of the fuel

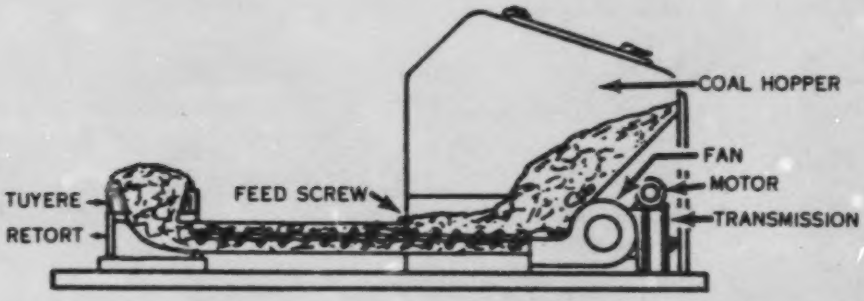


Figure 54. A diagram of an underfeed screw-type stoker.

bed or immediately above it. The coke that remains after the gaseous matter has been given off continues to move to the top. With air supplied, the coke then burns as its temperature rises above the kindling or ignition temperature. As the coke is burning, it is being pushed toward the ash discharge area. By the time the burning coke reaches the ash discharge area, the burning process is practically completed. In this area the remaining combustible matter or fuel burns completely before the ash is removed. The air enters through openings in parts of the stoker called tuyeres. These openings are usually located at the top or sides of the retort. Underfeed stokers may be classified by the number of retorts (single, double, or multiple) and the method of feeding (screw or ram). Single-retort stokers are either screw or ram fed. Mutiple-retort stokers which combine a gravity or overfeed action with the underfeed, are always ram fed. These stokers are used only on large boilers.

15-5. The screw-feed stoker is used for small boilers. It is available for coal-burning rates ranging from 100 pounds to 200 pounds per hour. This type of stoker gets its name from the fact that a screw-type conveyor moves the coal from the hopper or bin to the retort. A diagram of an underfeed screw-type stoker is shown in figure 54. The most important parts of this type of stoker are hopper, feed screw, retort, grates, fan, drive, and controls.

15-6. Hoppers vary in capacity from 375 to 2,000 pounds. Some hoppers have agitators, but others depend upon the slope of their sides to prevent the arching of the coal inside. Offset hoppers are often used to permit easier access to the boiler front for cleaning.

15-7. Feed screws are ordinarily made of cast steel, which is alloyed to provide strength and resist corrosion. Flights near the retort can be farther apart than those near the hopper; this is to prevent packing of the coal and to increase the shearing action of the screw. When coal packs in the tube, it rotates with the screw instead of sliding along the tube. This is called "slip." Excessive packing can jam the screw and prevent the motor from turning.

15-8. The size and shape of the retort depend on the coal-burning capacity of the stoker. In small units the retorts are nearly square; in larger units they are oblong. The burner head for underfeed stokers (shown in fig. 55) consists of a retort

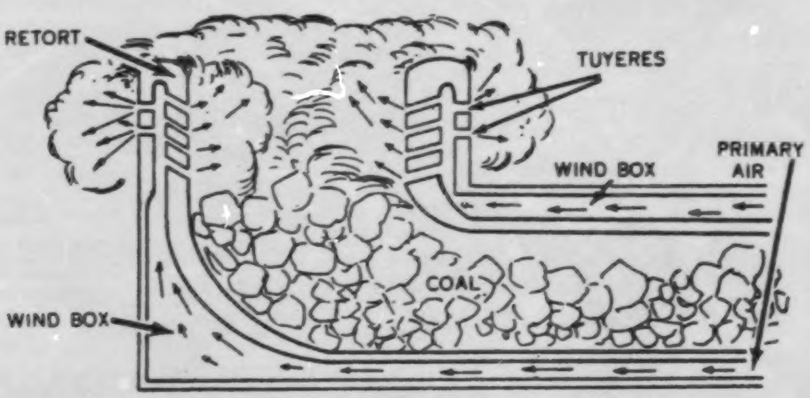


Figure 55. Stoker burner head.

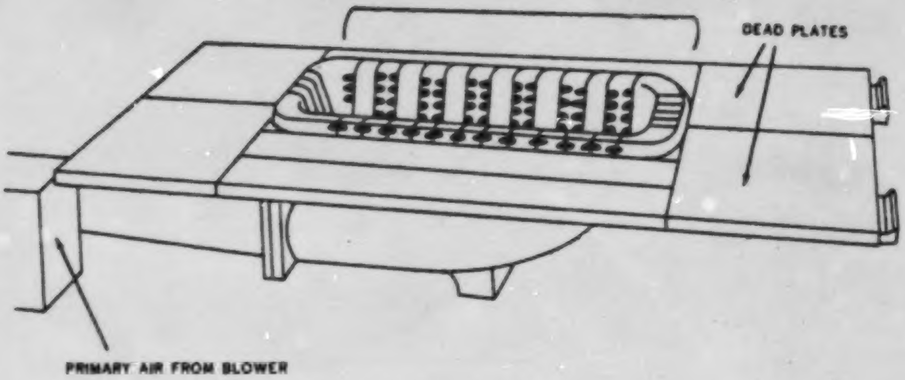

DEAD PLATES
PRIMARY AIR FROM BLOWER

Figure 56. A diagram of dead plates.

surrounded by a windbox and capped with a tuyere (pronounced twee-er). The tuyere distributes the air it receives from the blower evenly throughout the fire.

15-9. Surrounding the retort are heavy plates called "deadplates." The deadplate surfaces provide an air-cooled hearth upon which the clinkers will form. The air space below the deadplates serves as a duct for the primary air. A diagram of deadplates is shown in figure 56. Deadplates are not normally used in small installations because the primary air passage is constructed in the burner head.

15-10. Construction of the tuyeres is very important, as size, number, and position of the openings determine the coal-burning characteristics and, to a high degree, the ability of the burner to fuse ashes into a solid clinker that can be easily removed.

15-11. The power unit that is illustrated in figure 57 contains the fan, the driving motor, and the speed reducer (transmission). The motor and speed reducer are connected by a belt drive. The speed reducer is connected to the feed screw by means of a soft aluminum alloy shearpin. This pin will shear off and release the drive gear from the

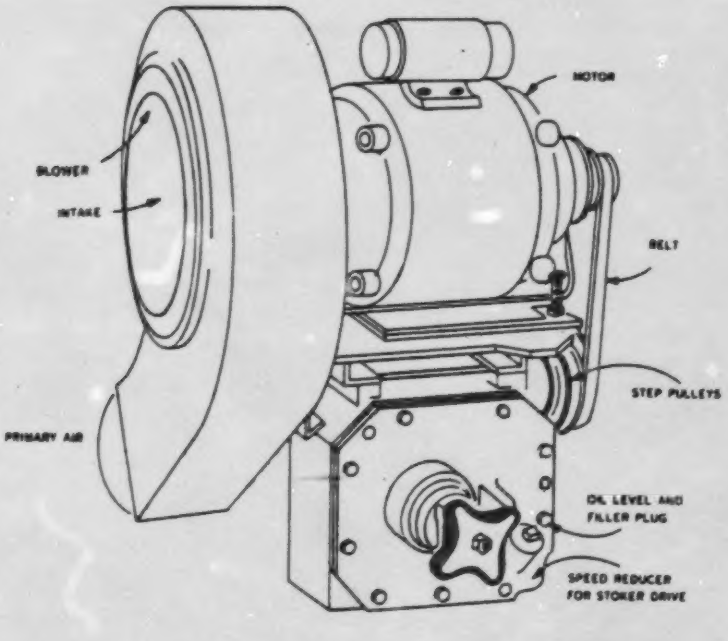

MOTOR
BLOWER
INTAKE
BELT
STEP PULLEYS
PRIMARY AIR
OIL LEVEL AND FILLER PLUG
SPEED REDUCER FOR STOKER DRIVE

Figure 57. A typical stoker power unit.

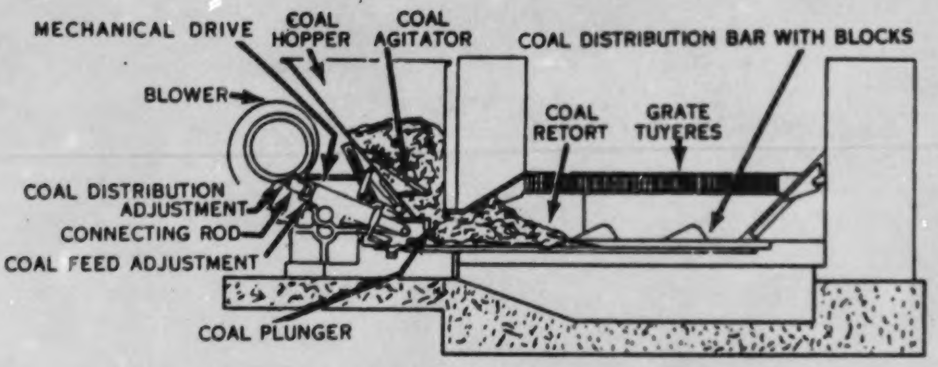


Figure 58. A typical reciprocating ram underfeed-type stoker.

screw if foreign material or the excessive packing of coal locks the screw so that it cannot turn. The rate of coal feed can be changed on most units by moving the belt on the step pulleys. However, some types of speed reducers have a ratchet lever for speed changing.

15-12. The reciprocating ram underfeed-type stoker, illustrated in figure 58, receives coal by gravity from the hopper and pushes it forward into the retort by means of a coal plunger. Ram underfeed-type stokers can be used to fire boilers of all capacities and ratings. They can be either the single or the double-retort type, with as many stokers added as are required for efficient boiler operation. A 1¼-inch moderate cooking nut coal, with not more than 50 percent slack, is preferred for use with a ram underfeed-type coal stoker.

15-13. The mechanical construction of a ram underfeed stoker differs considerably from that of the screw underfeed stoker. However, the means of providing air and the methods of electrical control are practically the same for both types.

15-14. *Spreader coal stokers.* Spreader coal stokers combine hand-firing and pulverized coal-firing methods. This method of coal feeding permits smaller particles to burn while they are suspended in the furnace or boiler. This action is nearly that of pulverized coal firing. (Pulverized coal firing will be discussed later in this chapter.) The remainder of the coal, however, is deposited on top of the burning coal, as in hand firing. Spreader stokers are not affected by the coking or noncoking properties of coal to as great an extent as are other types of stokers.

15-15. These stokers can handle coal ranging in size from coal dust to about one and one-fourth inches. They are particularly suited to the small sizes of coal which are not readily handled without pulverizing. The furnace burning volume must be adequate to permit fires to be burned in suspension. This volume is usually about 50 percent larger than that required of an underfeed stoker. The depth of the grate is limited by the ability of the stoker to spread coal evenly, and its width is limited by the width of the firebox. Several units can be placed side by side to provide the necessary capacity.

15-16. A spreader stoker consists of two major parts: the feeding machine and the grates. The feeding machine is required to feed the furnace at a rate sufficient to generate the required amount of steam. Also, it distributes the fine and coarse particles of coal evenly throughout the furnace burning volume, and on the grate. The grates catch those particles which are not burned in suspension and permit complete combustion. Provision is often made to return the fly ash which collects in various parts of the setting to the furnace to recover any combustible material. Overfire air is often supplied to improve combustion, and its use may be necessary if proper conditions of combustion are to be maintained at all ratings. The grates that are used have a large number of small holes or openings which allow even distribution of the air necessary for maintaining a thin fuel bed. Stationary or dumping grates are generally used. There is one spreader stoker that is manufactured with a traveling grate, and it is similar to the chain-grate stoker. However, this type of grate is used only on large boilers.

15-17. All spreader stokers operate with comparatively thin fuel beds. The stokers are sensitive to load changes, and they are well adapted to regulation by automatic combustion-control equipment. The thin fuel bed is advantageous for following fluctuating loads, and it also reduces banking losses. The supply of fuel on the grates can keep the fire going for only 5 or 6 minutes when the flow of fuel is interrupted.

15-18. There are two types of automatic spreader stokers. One type is the mechanical spreader stoker in which the feeder mechanism consists of the feeder and the thrower or spreader. The spreader is constructed with either an under-

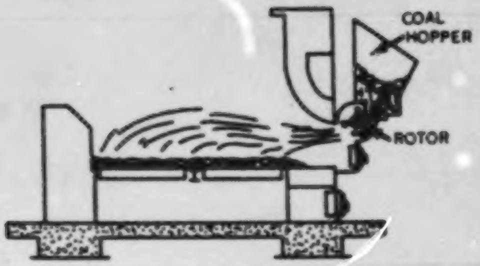


Figure 59. An underthrow spreader stoker.

throw or overthrow rotor. An underthrow rotor receives the coal directly and throws it into the furnace, as illustrated in figure 59.

15-19. A stoker that is fitted with an underthrow rotor picks up the coal out of a circular tray and throws it into the furnace. The paddles (rotor blades) are usually set in two or four rows around the rotor. The paddles in one row are twisted at an angle to throw the coal to the right while those in the next row throw it to the left. In some designs, the paddle is curved to provide uniform crosswise distribution. An oscillating plate or a ratchet-driven roll feeder is used to supply coal to the rotor. The rate at which the coal is fed is regulated by varying the length of the stroke of the oscillating plate or the speed at which the roll feeder is turned. The distribution of fuel along the length of the grate is regulated by changing the speed of the rotor or by changing the position of the spilling plate or circular tray.

15-20. The feeder mechanism, the grates, and the air supply ducts are usually constructed to operate as a unit. The feeding machines are normally driven from a single line shaft, each having its own drive gearing. Sections of the fire can be cleaned alternately by shutting off the fuel feed of one machine and allowing the fuel to burn out before disposing of the ash.

15-21. The second type is the pneumatic spreader stoker, illustrated in figure 60, which can be used with boilers having heating surfaces up to about 5,000 square feet. This type of stoker features a feeding mechanism and hopper located 20 feet or more from the firebox of the furnace. However, this feeding mechanism can also feed coal directly from a coal bin or a hopper. Coal is moved from the hopper by a feeder screw which carries it in the loose state to a transfer housing where a stream of air from a blower picks it up and conveys it through the pneumatic tube to the spreader nozzle. Coal distribution over the entire grate is regulated by the spreader nozzle. The feeder screw, as well as the blower, is driven by an electric motor through multiple speed transmission or some type of variable-speed drive unit.

15-22. Pneumatic spreader coal stokers are usually equipped with grates similar in construction to those found in the mechanical spreader stokers.

15-23. *Traveling-grate coal stokers.* Traveling-grate or chain-grate coal stokers are adapted to burn fuels that do not require agitation, such as small sizes of anthracite, the free-burning coals of the Midwest, and lignites.

15-24. The traveling-grate stoker shown in figure 61 is a typical example of this type. The traveling-grate stoker consists of a cast iron and steel framework, which supports the traveling grates. The traveling grates consist of cast iron carrier bars and small iron castings called "keys." The carrier bars are connected to an endless traveling chain which is driven from the front of the stoker. The number of chains and the length of the grate bars depend upon the width of the stoker.

15-25. The rate at which coal is fed to the firebox of the furnace is normally regulated by changing the travel speed of the grates. This change is accomplished through variable-speed transmissions. The grates can be powered by either a

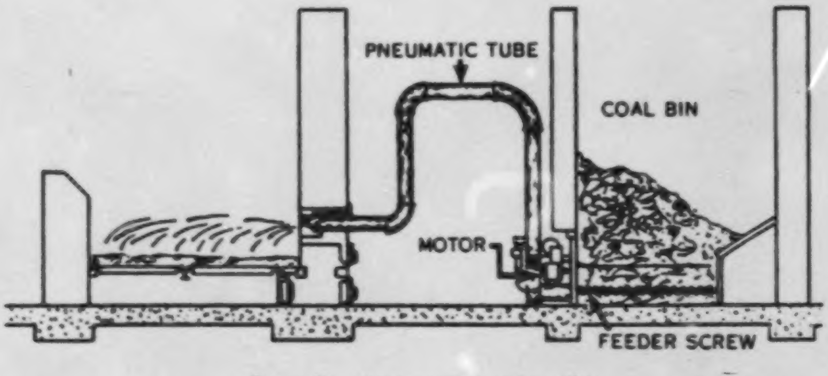


Figure 60. A pneumatic spreader stoker.

59

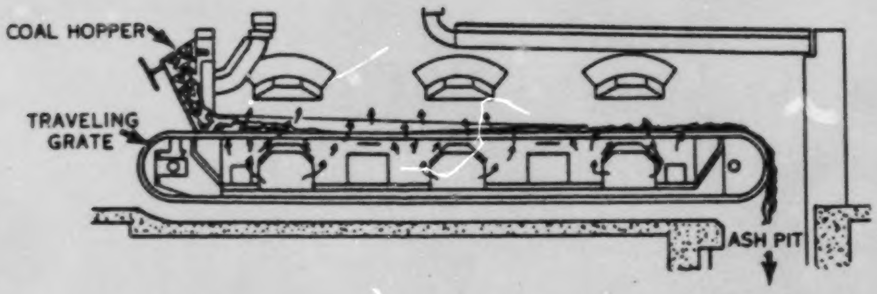


Figure 61. Traveling-grate stoker.

gasoline or steam engine, a steam turbine, or an electric motor.

15-26. The coal hopper mounted at the front of the stoker has an adjustable grate, which regulates the depth of the fuel bed. Fuel is burned as the grate travels from the front to the rear of the furnace firebox. The ashes are discharged into a pit as the grates pass over the rear sprocket. The firebox sometimes has water-cooled surfaces in areas of severe wear or clinker formation. The space between the grates is divided into zones, and the flow of air into each of these zones is controlled by dampers. This is necessary to attain uniform combustion, because the resistance of the fuel bed to the flow of air decreases as the grates move to the rear. It is practically impossible to secure proper air distribution when these zones are not provided. Firebox design depends to a certain extent upon the kind of fuel used. Overfire air is often supplied at very high velocities to increase turbulence and thereby mix the unburned gases with air to increase combustion efficiency.

15-27. *Pulverized coal heating unit.* A pulverized coal burner is one that burns coal which has been reduced to powder so fine that it floats in the air. This type of coal burning is called pulverized coal firing. Pulverized coal firing has many advantages, including high efficiency, ease in following load changes, ease in maintaining good combustion, wide range of usable fuels, and absence of any part of the equipment in the firebox of the furnace. The major disadvantages are the higher cost of the equipment, increased maintenance of brickwork due to the finely divided ash in the flue gases, and danger of explosion. These disadvantages usually make the use of pulverized coal firing for small heating units uneconomical and undesirable. We have been discussing the various types of stokers; now we will study about their controls.

15-28. **Automatic Stoker Controls.** Furnace control systems for stokers include the same controls as those used for hand firing, with the addition of a stoker control. Stoker controls for gravity warm-air, forced warm-air, hot-water, and steam systems are of the same type and operate on the same principle. However, the safety controls are constructed differently, since one type must respond to air temperature changes, a second type to water temperature changes, and a third type to the variations of steam pressure.

15-29. *Gravity warm-air stoker controls.* The essential stoker controls for a gravity warm-air heating system include the thermostat, the limit control, and the stoker control. A simple wiring diagram including these controls is shown in figure 62.

15-30. The purpose of the thermostat is to start the stoker motor when the room temperature drops below the point at which the thermostat is set, and then stop the motor when that certain temperature has been reached.

15-31. The limit control is a safety device. It stops the stoker motor if the temperature of the furnace becomes excessive because of the failure of the thermostat or the stoker control to function properly.

15-32. The stoker control unit, shown in figure 63, is a timer and relay that controls the stoker. This unit also permits the maintenance of a minimum fire during warm weather when the thermostat does not call for heat. This is done by means of an electric mechanism which periodically operates the stoker motor for short periods of time.

15-33. Normally, the timing mechanism is factory adjusted for a 2-minute operation every half hour, but the length and frequency can be changed when desired. Figure 64 explains how to change the setting of a timer.

15-34. *Forced warm-air stoker controls.* The stoker control circuit for a forced warm-air system includes the same controls as those used in the gravity warm-air system. However, in addition, the system includes a blower motor, blower switch, a limit switch, and an overrun blower switch. When the furnace is heated to the proper temperature, the blower switch starts the blower. If the blower

67

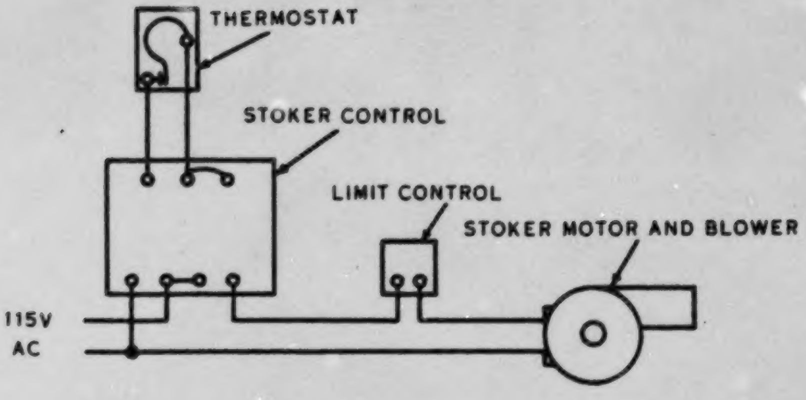


Figure 62. A wiring diagram of gravity warm-air stoker controls.

switch fails to start the blower, then the limit switch protects the furnace from overheating by shutting off the stoker. However, if the limit switch fails to operate, then the overrun blower switch turns on the blower to cool the furnace.

15-35. *Hot-water and steam systems stoker controls.* The stoker controls for hot-water systems and steam-heating systems are similar and perform the same function as those used with gravity and forced warm-air systems. The main difference lies in the method of operating the safety devices such as the limit controls. These devices are operated by temperature changes of the water in hot-water heating systems and by the variation of steam pressure in steam-heating systems.

15-36. For both hot-water systems and steam-heating systems, another electric circuit and the controls are added to automatically feed water to the boiler. The circuit and the controls perform the function of shutting off the stoker when the water in the boiler becomes too low for safe operation. The boiler water level is controlled by a boiler water control valve.

15-37. You have now completed reading about the controls required for operating stokers. In the next group of paragraphs you will study the installation of stokers.

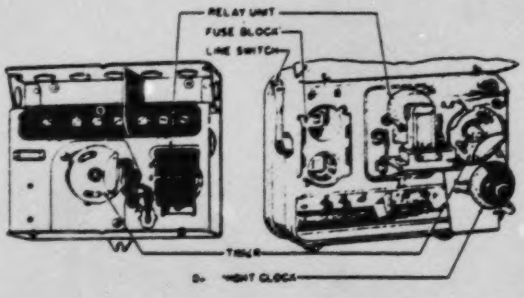


Figure 63. A typical stoker control unit.

15-38. **Installing Automatic Stokers.** You have learned in the previous paragraphs how stokers are constructed, also stoker types and the controls needed to operate them. In the following text you will study information that pertains to the installation, operation, and maintenance of these stokers.

15-39. *Underfeed screw stokers.* Before you install a new underfeed screw-type stoker, it should be thoroughly checked to see that there are no broken or missing parts. The voltage, phase, and frequency of the electric current that is available must be the same as shown on the stoker motor name plate.

15-40. The furnace should be thoroughly cleaned to remove any material that might obstruct the stoker installation. The windbox and tuyeres are the first to be installed. They are placed in their approximate location through the ashpit door or any other convenient opening. The hopper, coal tube, retort, screw, and transmission are assembled and also put in the correct locations. The windbox is bolted to the retort and the complete assembly is leveled.

15-41. When a solid refractory hearth is used, it is necessary to seal around the windbox and the

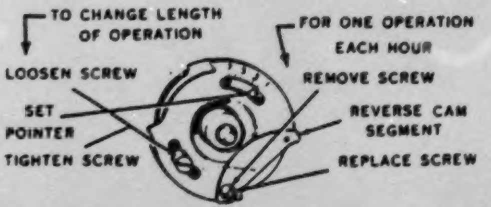


Figure 64. Changing the timer setting.

coal tube. If a deadplate or a ventilated hearth is used, this space is left open. Plastic furnace cement is used to seal all joints in the air duct and around the air duct and coal feed tube. The control system can then be connected.

15-42. Before you start a newly installed stoker, you should check the oil level in the transmission and test the feed screw to insure that it turns freely.

15-43. *Spreader stokers.* The spreader stokers are installed at the front of the furnace above the regular coal feed door, as shown in figure 59. Stokers of this type are usually more difficult to install in a furnace than most underfeed stoker units, because part of the furnace must be redesigned. In addition, the grates must be changed because the feeder mechanism, the air blower, and the grates are constructed to operate as a unit. However, when a furnace is designed to take a specific stoker, the installation is relatively simple. It is recommended that the instructions of the manufacturer be followed when installing spreader-type stokers. The pneumatic coal stokers which utilize the pulverized coal burner should be installed in accordance with the National Board of Fire Underwriters' standards for "Installation of Pulverized Fuel System."

15-44. *Traveling-grate stokers.* Traveling-grate stokers are also more difficult to install than underfeed screw-type stokers. A typical overfeed traveling-grate stoker, showing the traveling grates and the coal hopper, is illustrated in figure 61. When installing a traveling-grate stoker, special provisions should be made for the foundation for the traveling-grates and the ashpit. It is recommended that you follow the instructions of the manufacturer when installing traveling-grate stokers.

15-45. **Operating Automatic Stokers.** The operation of stokers may seem complicated to you at first glance. However, by applying the knowledge you will gain here about operating the stokers, you should be able to effectively operate automatic stokers with but little assistance. In the following paragraphs you will find information regarding the operation of underfeed screw stokers, spreader stokers, traveling-grate stokers, and pulverized-coal firing. By studying these discussions you will be able to understand how the stokers operate.

15-46. *Underfeed screw stokers.* As the fuel travels up from the bottom of the retort, the temperature of the coal gradually rises, causing the volatile matter to vaporize, mix with the air supply, and pass up through the hotter zones of the fuel bed. The temperature of the gaseous mixture rises until it ignites and burns.

15-47. The coke that remains after the volatile matter has been vaporized continues to move to the top. Its temperature rises above the ignition temperature, air is supplied, and the coke burns. As the coke is forced up, it also moves outward toward the ash discharge area. The remaining combustible material burns completely in this area before the ash is removed.

15-48. It is considered good practice to check the operation of a stoker at the end of the heating season. All of the ashes and clinkers should be removed from the firebox. The refractory lining should be inspected for broken bricks, and all broken bricks should be replaced. The tuyere holes should be examined and those that are clogged should be cleaned out. The combustion chamber and smokepipes should be cleaned of all soot and fly ash. You should also check the oil level in the reduction gear housing. If the level is low, you should add sufficient oil to bring it up to the proper level.

15-49. When you start a fire in the furnace, allow the stoker to operate until the coal is about 1 inch below the top of the tuyere. Then place some paper and scraps of wood on top of this coal. Make sure that the stoker air adjustment is closed. After the kindling wood has ignited, start the stoker and increase the air flow. As the fuel depth increases, increase the volume of air. When the fire is burning in the normal manner, observe the fire for a while. A red, smoky fire indicates insufficient air or too much fuel. Make your adjustments accordingly. A clear, light yellow, billowy flame without smoke indicates a normal fire.

15-50. *Spreader stokers.* Spreader stokers permit the burning of fine coal particles in suspension and the remainder of the coal on the grates. This method permits easier stoker operation and reduces clinker formation, because the fire on the grates is quite thin.

15-51. The supply of coal in a spreader stoker lasts only 5 or 6 minutes. You can check the thickness of the fuel bed by stopping the fuel feed and noting the rate at which the fuel on the grates is burned. If the ashes are ready to dump in from 5 to 6 minutes, the thickness of the fuel bed is correct. You adjust the spreading mechanism for uniform thickness of the fuel over the grates to obtain the complete mixing of fuel and air. Then you adjust the air feed to produce efficient combustion.

15-52. The fire must be cleaned at regular intervals, usually when the ashes are from 3 to 6 inches thick on the grates. You should not allow the fuelbed to become too thick or clinkers will form. Remove the ashes from the ashpit promptly.

15-53. *Traveling-grate stokers.* Traveling-grate stokers provide the means for burning very fine coal or coal that contains ash and has a low fusing temperature. These stokers are not suited to burn caking coal or coking coal.

15-54. The feeding of coal by a traveling-grate stoker can be increased or decreased by changing the thickness of the coal-feed ribbon to the stoker, or by increasing or decreasing the rate of grate travel. The normal speed of the grates varies from two and one-half to three and one-half inches per minute (ipm). The coal should be completely burned before it reaches the back of the furnace.

15-55. Excessive burning of the grate links indicates that an appreciable amount of burning coal is passing over the back end of the grates into the ashpit. However, if all the coal is burned long before it reaches the back end of the furnace, too much air is being admitted and is causing an excessive amount of heat to be carried away by the flue gases. You can determine the proper feeding of coal by observation or by making a flue-gas analysis.

15-56. *Pulverized coal heating unit.* Pulverized coal is burned in the furnace almost instantly. It is carried into the furnace with the stream of primary air, but this amount of air is not sufficient to complete combustion. After the coal enters the furnace and combustion begins, the additional secondary air moves in to complete the combustion.

15-57. The procedure for changing the rate of pulverized coal moving into the furnace varies widely. Both the quantity of coal and the primary air may be changed or the primary air may be kept constant while the coal feed is adjusted. In either case, the total air supply must vary with and be in proportion to the coal.

15-58. Since there is practically no residual coal in the furnace, it is possible to change the output of a pulverized coal heating unit very quickly. Should the flame become unstable during combustion, which amounts to a series of small explosions, you should increase the rate of fuel flow so that a sufficiently rich mixture is present at the burner tip. You should always handle pulverized fuel in a manner which prevents the formation of an explosive mixture of dust and air.

15-59. Maintaining Automatic Stokers. You will find when you are called upon to maintain an automatic stoker that at the first glance maintaining the stoker may look difficult. However, if you follow the manufacturer's recommendations and use the information in pertinent military publications, you will not have the difficulty you might otherwise have accomplishing the maintenance required for keeping your stoker operating. To obtain the best service, you should follow the instructions and specifications of the manufacturer when lubricating all moving parts. You should keep the ashpit clean at all times. Always report immediately any unusual operating conditions to your superior.

15-60. *Underfeed stokers.* Always keep sufficient coal in the retort to prevent the fire from reaching this section of the stoker. Inspect the windboxes and remove any accumulations of siftings. You should also make frequent inspections of the firebox brickwork.

15-61. The most common cause of trouble with a screw feed stoker is the stoppage of the coal feed screw by foreign particles lodging in the feed-screw tube. Usually, the shearpin shears. But before replacing the shearpin, you must remove the foreign particles from the tube so that the feed screw turns freely.

15-62. *Spreader stokers.* Examine the windbox of a spreader stoker periodically and keep it clean. Check the operation of the feeder mechanism to assure equal distribution of coal. If wet coal sticks in the hopper, push it into the feeder with a rod.

15-63. *Traveling-grate stoker.* You can adjust the tension on the grate of the traveling-grate stoker with the tension screws at the back sprocket bearing. Adjust the screws on both sides until the chain is tight, then loosen the screws slightly. Many traveling-grate stokers are equipped with ledge plates on the sides to prevent excessive air leaks. These ledge plates must be adjusted properly for efficient combustion.

15-64. *Pulverized coal heating unit.* It is necessary to keep checking the operation of the pulverizing mill, blower, burners and pipes, ducts and electrical controls of the pulverized coal heating unit. The refractories should be checked frequently for cracks or disintegration. You should adjust the primary and secondary guide vanes as required, and keep the burners clean.

16. Smokepipe and Chimneys

16-1. You have come to the point where you have gained considerable knowledge about both cast iron and steel coal furnaces. You have also studied methods of handfiring them and using stokers. Now, you are ready to study about the means for handling the byproducts of combustion. You will recall that we previously discussed smokepipes and chimneys—their function and operation. Now you are ready to study about installation and maintenance of smokepipes and chimneys.

16-2. **Installing Smokepipe.** The proper installation of a smokepipe, or "breeching" as it is sometimes called, is of prime importance to the operation of the heating unit. The smokepipe coming from the firebox of a furnace or boiler should be at least eighteen gauge or heavier metal and must be at least as large as the connecting collar of the heating unit. The pipe should be pitched upward from the collar at least 1 inch for each linear foot. You should avoid the use of elbows or 90° bends whenever possible because bends or elbows tend to reduce the flow of the combustion gases to the chimney. The smokepipe connections at the heating unit collar and at the chimney must be airtight to prevent the leakage of combustion gases into the furnace room. Airtight connections also keep unwanted outside air, which cuts down the amount of draft on the heating unit, from being pulled into the pipe. Some types of heating units have hinged check drafts installed on the upper side of the pipe. These check drafts are omitted, however, when some types of coal are used, and a balanced atmospheric type of draft regulator is installed to regulate chimney draft. You will recall that we discussed this draft regulation in Chapter 3. The basic operating principles of these regulators—whether used for space heaters, furnaces, or boilers—is the same, even though the size may differ.

16-3. **Maintaining Chimneys.** The proper combustion of coal in the firebox of a furnace or boiler depends upon the size, type, and condition of the chimney that carries away the flue gases. Every pound of coal requires from 150 to 250 cubic feet of air for complete combustion. For this reason, sufficient draft must be maintained by the chimney through the fuel bed to supply the proper amount of air. It is, therefore, mandatory that a chimney have sufficient height and area, and that the chimney wall be reasonably free from air leaks. The round chimney is the most efficient. However, rectangular chimneys are often used.

16-4. Chimneys must be checked for air leaks and soot formation. You can make these checks by examining the chimney with a hand mirror placed at the proper angle in the cleanout door at the base of the chimney, or at the opening provided for the smokepipe, as illustrated in figure 65. You can determine whether the flue is clear or whether it has been obstructed by fly ash, fallen or displaced bricks, or birds' nests, and the like. If an obstructed condition is found, a heavy weight suspended from a strong rope and dropped down from the top of the chimney will often clear the obstructions. If they cannot be cleared in this manner, then it is necessary to obtain the services of an experienced chimney man. Figure 66 shows obstructions in a chimney.

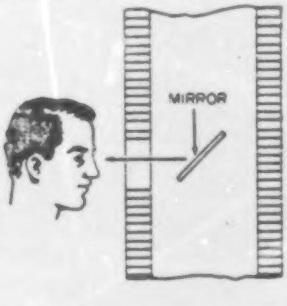


Figure 65. Checking a chimney with a hand mirror.

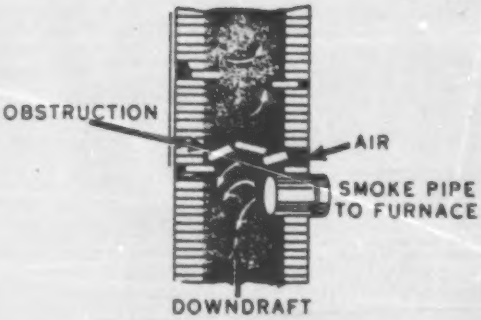


Figure 66. Obstructions in a chimney.

16-5. If you suspect that there are leaks in the chimney, you should insure that all openings in the chimney are tightly closed. Also, look for caps which do not fit tightly in the unused openings in the chimney. At the base of every chimney there is usually a cleanout door or opening to permit the removal of soot or accumulated fly ash. Often these will be found partially open or rusted out, so close the doors tightly or replace them. See that any unused stoves or heaters connected to the chimney have all dampers closed tightly, including the chimney damper, since much of the effectiveness of the chimney can be lost by these large air leaks.

16-6. Then you should examine the chimney at every point possible. This is done to see that none of the mortar has fallen out from between the bricks. Leaks of this kind can cause an otherwise good chimney to give a poor draft. Assure that all of the joints between the bricks are cemented and made airtight. Figure 67 illustrates loose bricks with air leaks.

16-7. A chimney must have a cross-sectional area equal to or larger than the area of the flue outlet of the furnace. That is, the inside diameter

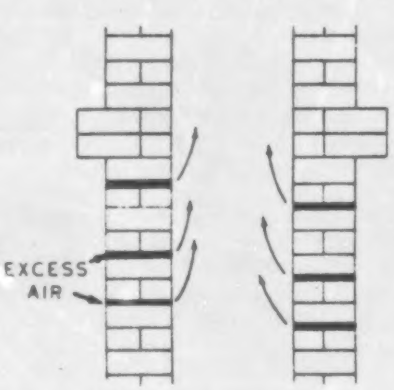


Figure 67. A chimney with air leaks.

of a round chimney must be equal to or larger than the inside diameter of the flue outlet, whereas the inside dimensions of a rectangular chimney must be at least two-thirds of the inside diameter of the flue outlet. As a general rule, the cross-sectional area of chimneys must be increased 4 percent for every 1,000 feet of altitude above sea level. Chimneys should be extended at least 3 feet above the peak of the roof and should never be less than 15 feet tall, even for small stokers. It is recommended that the manufacturers' specifications be followed when altering or installing new chimneys. You should never reduce the size of the smokepipe before it enters the chimney. The pipe should fit tightly at all connections, and pitch upward throughout its entire length until it enters the chimney.

16-8. Sluggish chimneys can sometimes be remedied by using a "toothpick" joint, which is illustrated in figure 68. When a chimney has too large a flue or a weak draft, you can attach the toothpick joint to the smokepipe and let it extend into the flue so that point "x" is in the approximate center of the chimney.

16-9. Some chimneys are built on a shelf the bottom of which is only a few inches below the smokepipe opening. (See fig. 68.) A strong eddy current is usually formed at the bottom of the chimney, and the toothpick joint will assist in creating a good draft.

16-10. In cases where two smokepipes enter a chimney opposite each other, it is best to use one length of pipe with a vee cut in it and have the end closed as shown in figure 69. This gives both connections an equal draft and eliminates the eddy currents which might reduce the draft in one or both smokepipes.

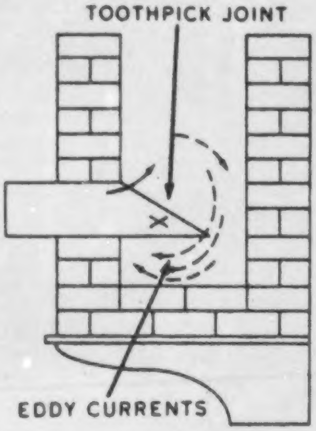


Figure 68. A toothpick joint installed in a chimney built on a shelf.

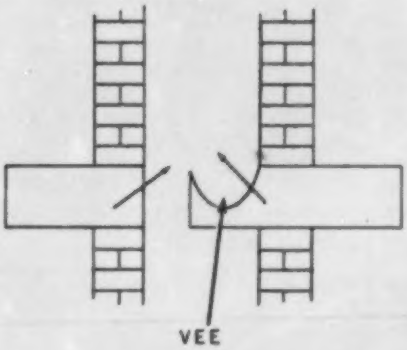


Figure 69. A two-smokepipe vee-cut installation.

CHAPTER 5

Oil Burners and Controls

FOR MANY years the American housewife had to contend with coal dust and ashes. These created a very serious cleaning problem in her house. Often she had to carry coal into the home for the stove or furnace, and take the ashes out. However, the discovery of oil and the use of its byproducts in heating systems have all but eliminated this part of her cleaning problem.

2. Oil has a number of advantages over coal when used for heating purposes. The cost of handling oil is lower, because less labor is required to do it. A much smaller storage area is required to store a comparable amount of fuel oil. The oil feasibly may be dropped from aircraft to otherwise inaccessible areas. The burning of oil is easier to control, and it is cleaner to handle. Oil does not deteriorate when properly stored. In spite of all these advantages that oil has over coal, we should not be content to stop our comparisons here. Let's look into another area, such as the types of burners and controls that are needed for oil.

The burners which use oil can be classified as distillate, domestic, commercial, and industrial. The distillate burners include the range or perforated sleeve type and the natural draft pot-type or bowl-type burners normally used in the small space heaters, which were covered previously in this memorandum. Domestic oil burners are usually power driven and are installed in small heating plants for steam and hot-water generation. Commercial or industrial burners are used in larger central heating plants. In this chapter we are going to discuss various types of oil burners such as the high-pressure gun-type, low-pressure gun-type, vertical rotary, horizontal rotary and conversion-type burners which you will operate and maintain during your military career. There will also be discussions covering the construction, operation, and troubleshooting of each type of burner. The first type which you will study is the domestic oil burner.

17. Domestic Oil Burners

17-1. Domestic oil burners vaporize or atomize the oil and deliver a predetermined quantity of oil and air to the combustion chamber. Domestic oil burners operate automatically and maintain a desired rate of combustion. A classification generally recognized by the oil burner industry is based on design and construction. The three types of domestic burners that will be discussed are the gun-type high-pressure oil burners, gun-type low-pressure oil burners, and vertical rotary burners.

17-2. Gun-type domestic oil burners atomize the oil either by oil pressure or by low-pressure air through a nozzle. The oil system of a pressure-atomizing burner consists of strainer, gear pump, pressure-regulating valve, shutoff valve, and atomizing nozzle. The air system consists of a power-driven fan (with the means to throttle the air inlet), an air or blast tube (which surrounds the nozzle and electrode assembly), and tube vanes (which create turbulence for properly mixing the air with the oil). The fan and oil pump are generally connected directly to the motor. Atomizing nozzles are available for different angles of spray and oil flow rate for any particular installation. Flame shape can also be varied by changing the design of the air exit at the end of the air tube. The oil pressure normally used is about 100 pounds per square inch (psi), but pressure considerably higher than this is sometimes used.

17-3. Electric ignition is almost universally used to start the burning. The ignition is caused by stepped-up line voltage (approximately 10,000 volts) arcing between two electrodes. The electrodes are located near the nozzle, but they should not be in the path of the oil spray.

17-4. **Gun-Type High-Pressure Burners.** The high-pressure gun-type oil burner is the most popular type. Its simple construction makes necessary only two operating adjustments. The high-pressure burner, shown in figure 70, is a carefully designed and precision-built oil burner constructed for durability and long service. The high-pressure burner consists of motor, fan, ignition transformer, fuel unit, nozzle and electrode assembly, and the casting to which all of these parts are attached. The parts of a high-pressure gun-type burner are usually interchangeable with other burners of this type.

66

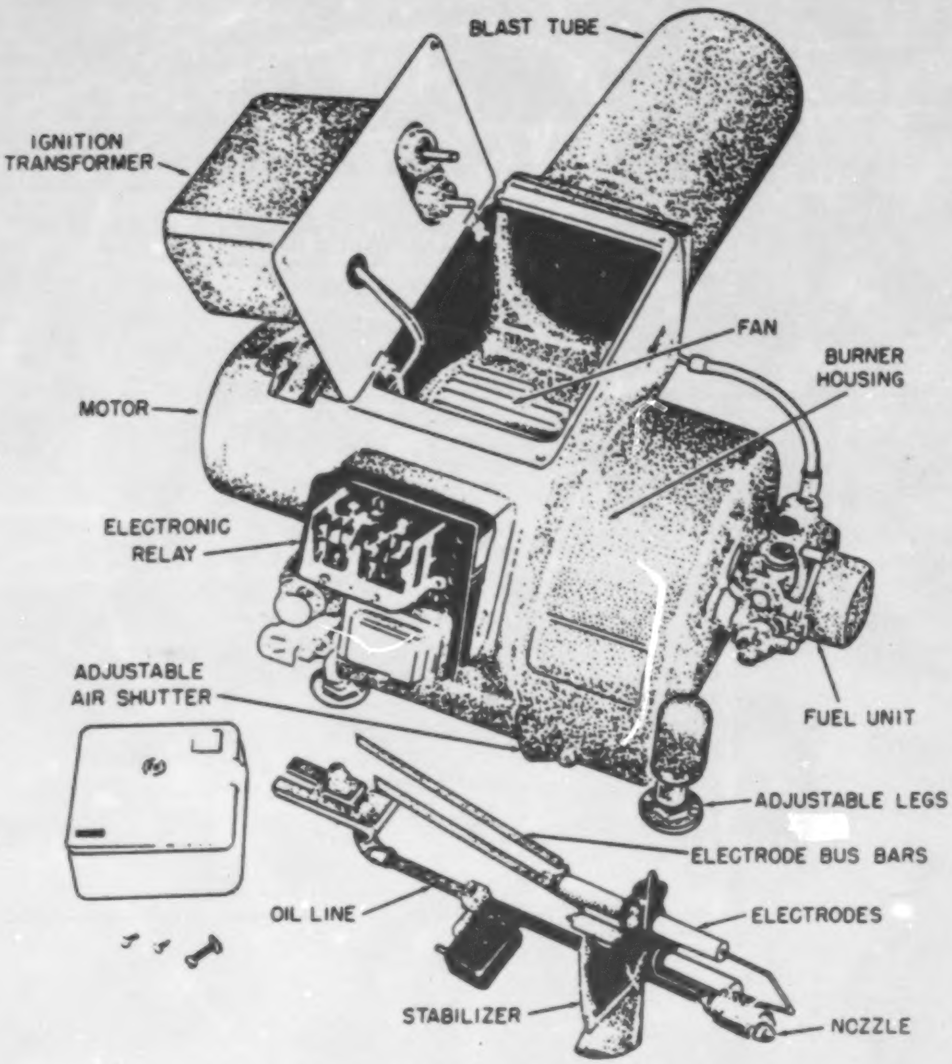

BLAST TUBE
IGNITION TRANSFORMER
FAN
BURNER HOUSING
MOTOR
ELECTRONIC RELAY
ADJUSTABLE AIR SHUTTER
FUEL UNIT
ADJUSTABLE LEGS
ELECTRODE BUS BARS
OIL LINE
ELECTRODES
STABILIZER
NOZZLE

Figure 70. High-pressure gun-type oil burner.

17-5. An electric motor, like that shown in figure 71, drives the fan and the fuel pump. The motor is specially designed and is an integral part of the burner. It is mounted on the burner by means of a two-, three-, or four-bolt flange. The removal of these bolts allows easy removal of the motor for repair or replacement. If the motor has oil cups, it should be oiled about twice a year. Special attention should be given to oiling the motor, because overoiling it can cause damage.

17-6. A rebuilt motor of the same rotation, mounting, and revolutions per minute (rpm) is generally used as a replacement in the event of motor failure. Basically, however, all oil burner motors are similar; consequently, replacement motors do not always have to come from the same manufacturer. The important factors are the direction of rotation, rpm, and mounting.

17-7. A fan or blower partially shown in figure 70, is better illustrated in figure 72, and is located within the burner fan housing. The unit is driven directly from the motor shaft, and it provides the necessary air to support combustion. The fan wheel is of multiblade design and capable of furnishing adequate air to the draft tube. The volume of air handled by the fan is readily controlled by an adjustable air shutter on the housing which controls the air intake to the burner.

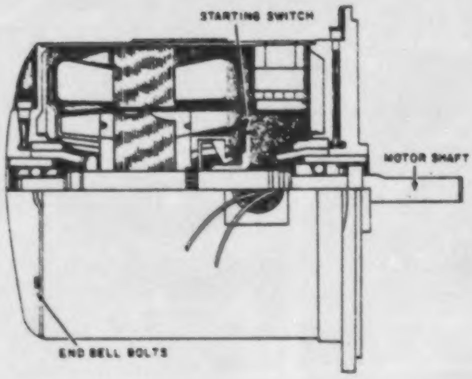


Figure 71. Cutaway view of an electric motor.

17-8. The ignition transformer, like that shown in figure 73, is usually located at one side or on top of the burner, and it provides the "step-up" from the line voltage of 110 or 125 volts to the 10,000 volts required by the ignition electrodes. The spark jumping across the gap between the electrodes provides heat which ignites the oil that is spraying from the nozzle. When replacing a burned-out transformer, you must be sure to replace it with one of the proper type or one that has identical mounting holes.

17-9. The fuel-units of a high-pressure gun-type burner may be either single- or two-stage units using one- or two-pipe supply systems. Each of these units has a specific application; therefore one unit must never be applied to the use for which the other is intended.

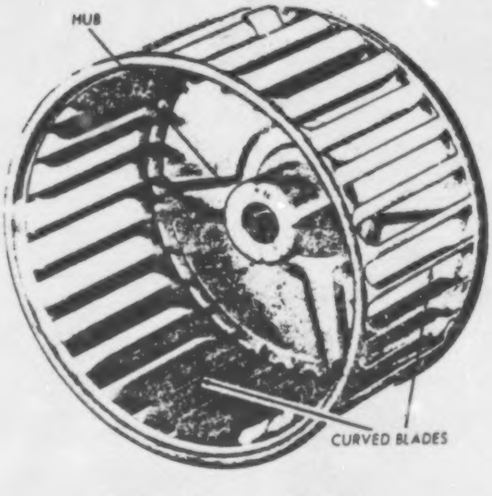


Figure 72. A multiblade fan.

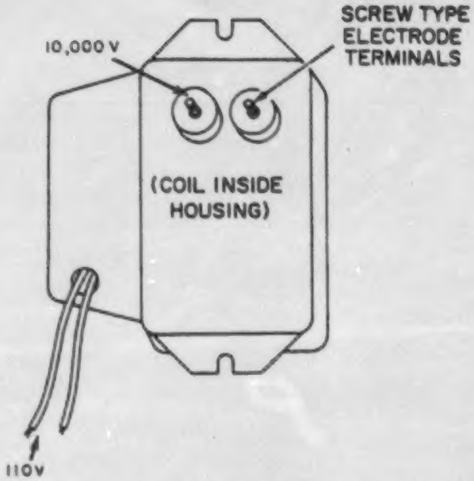


Figure 73. An ignition transformer.

17-10. *Single-stage fuel units.* The single-stage fuel unit has one pumping stage that takes the oil, fed by gravity into it, and applies sufficient pressure to force the fuel through the nozzle. The single-stage unit is, therefore, best adapted where an elevated tank is used and the oil is fed by gravity to the burner. Although the single-stage pump can be used, if necessary, for overhead piping installations, there is some danger of pump noise. The two-stage pump is therefore recommended for this installation. Figure 74 illustrates a single-stage fuel unit.

17-11. *Two-stage fuel units.* The two-stage fuel unit is very much like the single-stage unit, but it contains two complete pumping units. A two-stage unit is shown in figure 75. One pump lifts oil from the tank to the unit and delivers it to the second pump, which applies the required nozzle pressure. This two-stage unit is recommended for use with all outside underground tank installations as well as for the inside tanks connected to the burner through overhead piping. You should use a two-pipe system with a two-stage fuel unit. The pressure regulating valve has an adjusting screw to enable the operator to vary the pressure from 80 to 140 psi.

17-12. In the case of hum in the fuel tank, check the antihum diaphragm of the fuel pump. If it is broken or missing, replace it with one like that shown in figure 76.

17-13. *Nozzle and electrode assembly.* The nozzle and electrode assembly includes oil pipe, nozzle holder, nozzle and strainer, electrodes, insulators around the electrodes, a supporting clamp for all parts, and a static disk, as illustrated in figure 77.

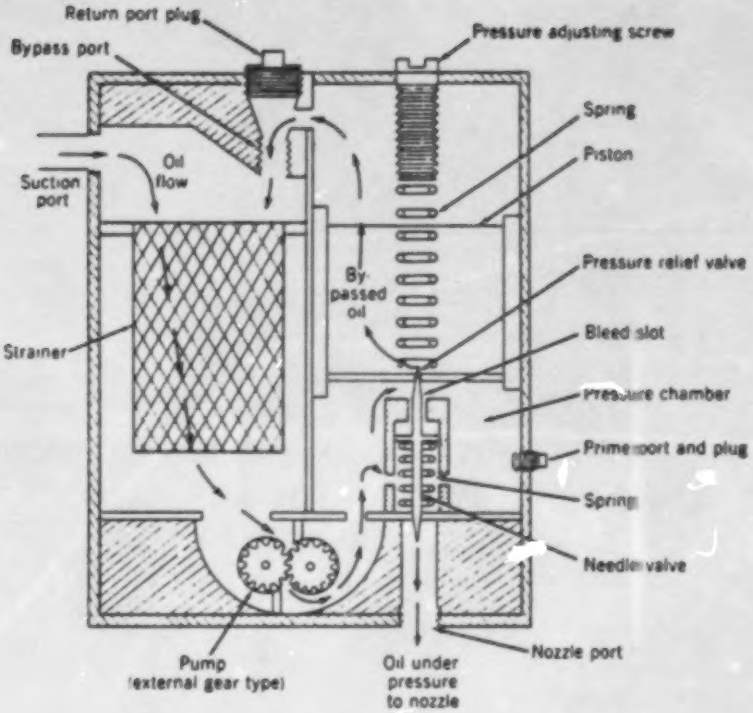

Return port plug
Bypass port
Pressure adjusting screw
Spring
Piston
Suction port
Oil flow
By-passed oil
Pressure relief valve
Bleed slot
Strainer
Pressure chamber
Prime port and plug
Spring
Needle valve
Nozzle port
Pump (external gear type)
Oil under pressure to nozzle

Figure 74. A single-stage fuel unit.

17-14. The high-pressure gun-type nozzle is rated in gallons per hour (gph), and the rating is stamped into the side of it. The nozzle that is selected depends on the size of the furnace or boiler. The angle of the spray is also stamped into the side of the nozzle. The size of the firebox determines what the angle of spray will be. A long, narrow firebox requires a smaller spray angle than a short, wide firebox. Care must be taken when selecting a nozzle to insure that the angle of the spray will not cause the flame to strike the sides or back of the firebox.

17-15. *Gun-Type Low-Pressure Burners.* The low-pressure gun-type oil burner is different from the high-pressure gun-type burner. The parts of a gun-type low-pressure burner are also different from the parts of other burners of this type. It is necessary, therefore, to study each type individually. Figure 78 illustrates a typical low-pressure gun-type burner.

17-16. Figure 79 shows the oil and air being brought together inside a compressor and mixed. This mixture is delivered into a separating chamber

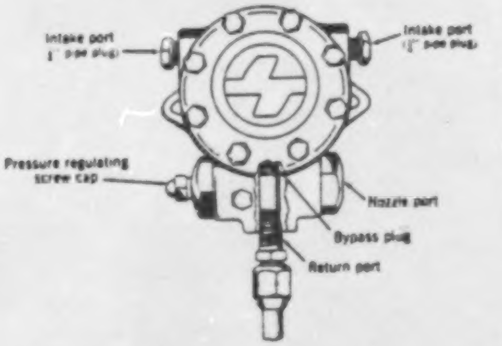

Intake port
(¼" pipe plug)
Intake port
(¼" pipe plug)
Pressure regulating screw cap
Nozzle port
Bypass plug
Return port

Figure 75. A two-stage fuel unit.

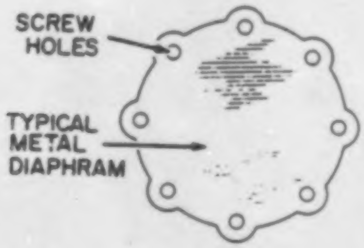

SCREW HOLES
TYPICAL METAL DIAPHRAM

Figure 76. Antihum diaphragm.

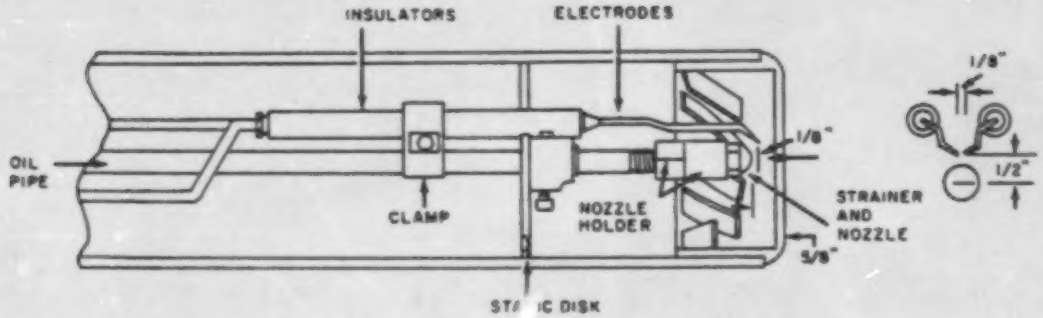


Figure 77. Nozzle and electrode assembly.

called a "sump," where it is separated. Then the oil and air are again brought together in an air friction-type nozzle and remixed. This basic cycle provides smooth oil travel aund uninterrupted delivery. The three indispensable parts of the gun-type low-pressure burner are the rotary compressor (which pumps the oil and air), the sump or separating chamber, and the nozzle. (The nozzle of the low-pressure burner is very different from the nozzle of the high-pressure burner.) This type of nozzle is illustrated in figure 80.

17-17. The air used for atomization of the oil is only a small portion of the air required for proper combustion. Consequently, a motor-driven blower, with the means of throttling the air supply, provides additional air. The oil-flow rate is controlled by adjusting the air atomizing pressure.

17-18. **Vertical Rotary Burners.** There are two distinct types of vertical rotary burners—the atomizing or radiant-flame burner and the vaporizing or wall-flame burner. The atomizing or radiant-flame burner, sometimes called the "suspended-flame burner," atomizes the oil by throwing it from the circumference of a rapidly rotating motor-driven cup. The radiant-flame burner is shown in figure 81. The burner must be installed so that the driving parts are protected from the heat of the flame by a hearth or refractory material at about grate level. The oil may be fed by a pump or by gravity, while the draft may be either forced or a combination of natural draft and forced draft. The air-oil mixture burns as a suspended flame without striking the furnace walls.

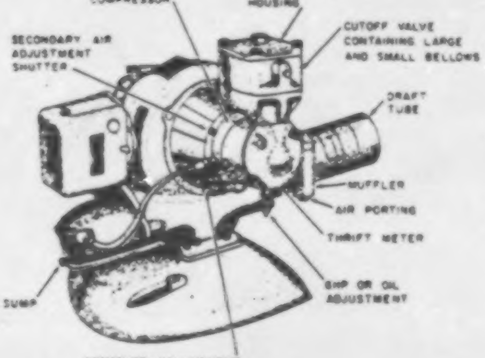


Figure 78. Low-pressure gun-type burner.

17-19. The vaporizing or wall-flame burner, also called the "blue-flame burner," has an oil distributor and fan blades mounted on a vertical shaft that is directly connected to a motor. A refractory hearth shields the motor from the flame. The oil distributor projects the oil to a flame ring, which may be either refractory material or metal. The flame ring of the wall-flame burner is shown in figure 82. The hot flame ring vaporizes the oil; and the oil vapor mixes with air and burns with a quiet, blue flame that sweeps the walls of the furnace. Wall-flame burners can use electric, gas-electric, or gas ignition devices. Satisfactory performance in small furnaces requires the use of high-grade furnace oil.

17-20. **Installing Domestic Oil Burners.** Satisfactory heating with domestic oil burners depends not only on the selection of suitable equipment, proper installation, and operation, but also on the condition of the building to be heated. This condition of the building is particularly important with respect to heat loss (tightness of doors and windows) and the location of the heat sources. The oil burner must be installed by qualified and experienced mechanics, in strict accordance with the manufacturer's instructions. Details of combustion chamber size and shape, and the positions of the burner and auxiliary equipment can be found in installations manuals that are furnished by the oil burner manufacturers. The fuel supply tanks and piping must be installed in accordance with the National Board of Fire Underwriters Regulations governing the installation of oil-burning equipment.

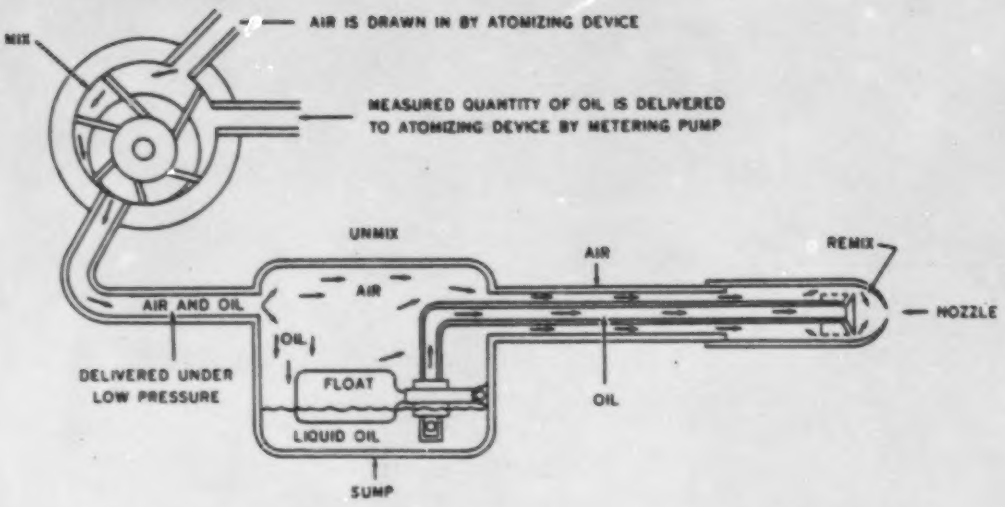

MIX
AIR IS DRAWN IN BY ATOMIZING DEVICE
MEASURED QUANTITY OF OIL IS DELIVERED TO ATOMIZING DEVICE BY METERING PUMP
UNMIX
AIR
REMIX
NOZZLE
AIR AND OIL
AIR
OIL
FLOAT
DELIVERED UNDER LOW PRESSURE
LIQUID OIL
OIL
SUMP

Figure 79. A schematic diagram of air atomization employed by a low-pressure gun-type burner.

The electrical connections must conform to the National Electric Code.

17-21. The chimney to which the oil burner is connected must be constructed so that ample draft is available at all times for safe operation. Flue dampers must be constructed so that not more than 80 percent of the internal area of the flue can be closed off, and a draft regulator is required. The furnace in which the oil burner in installed must be adequately ventilated to assure sufficient air for complete combustion of the oil.

17-22. **Operating Domestic Oil Burners.** You will follow the recommendations and procedures furnished by the manufacturer of the specific unit when operating domestic oil burners. After the burner has operated long enough to warm the com-

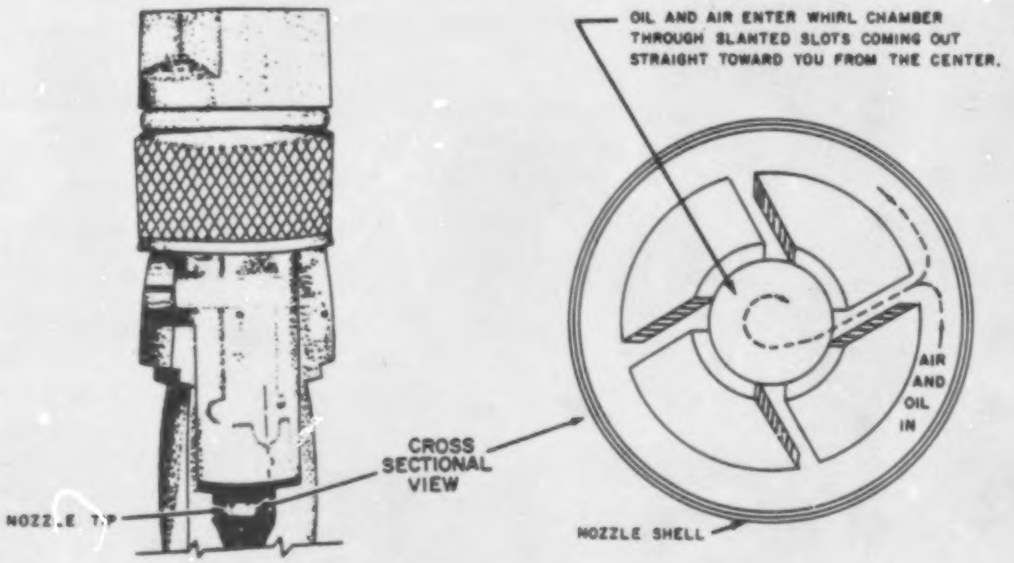

OIL AND AIR ENTER WHIRL CHAMBER THROUGH SLANTED SLOTS COMING OUT STRAIGHT TOWARD YOU FROM THE CENTER.
AIR AND OIL IN
CROSS SECTIONAL VIEW
NOZZLE TIP
NOZZLE SHELL

Figure 80. Low-pressure nozzle and a cutaway view of the nozzle.

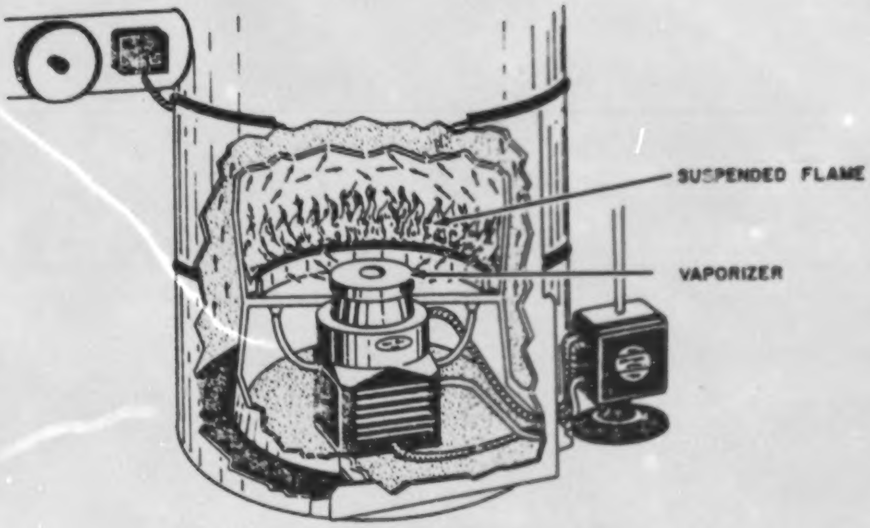

SUSPENDED FLAME
VAPORIZER

Figure 81. Cutaway view of a radiant flame burner.

bustion chamber, you should make an air adjustment as you watch the flame for proper color. After you have adjusted the fire visually as well as you can, you should analyze the combustion with an orsat to insure proper combustion. You then allow the burner to operate for 2 or 3 weeks before you check the combustion again with an orsat and use the draft gage.

17-23. **Troubleshooting Domestic Oil Burners.** Some of the common troubles, along with their

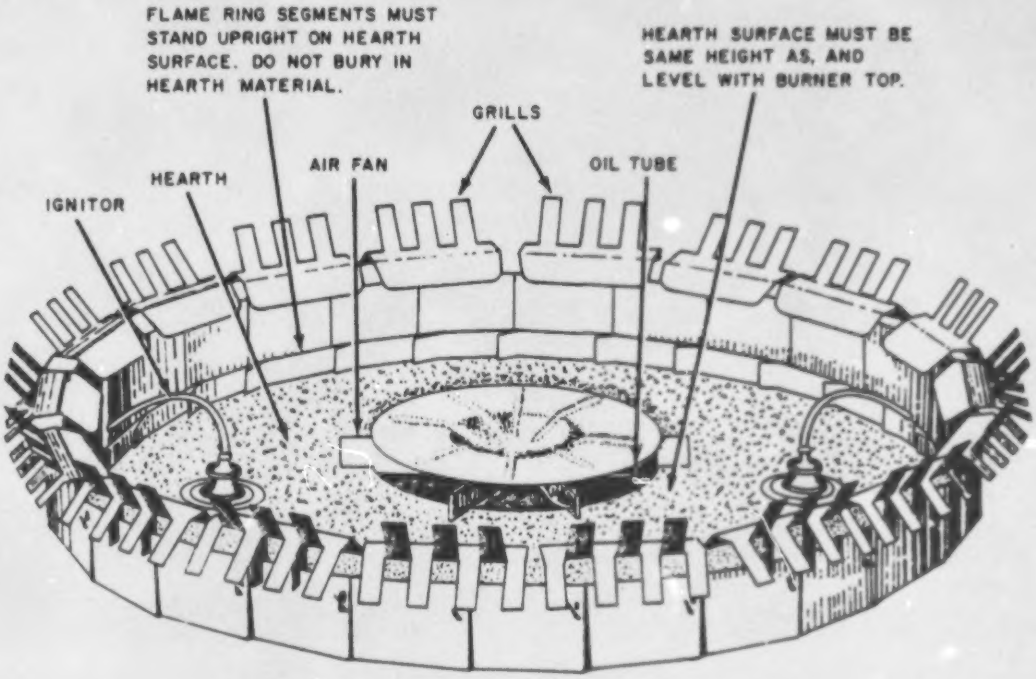

FLAME RING SEGMENTS MUST STAND UPRIGHT ON HEARTH SURFACE. DO NOT BURY IN HEARTH MATERIAL.
HEARTH SURFACE MUST BE SAME HEIGHT AS, AND LEVEL WITH BURNER TOP.
GRILLS
IGNITOR
HEARTH
AIR FAN
OIL TUBE

Figure 82. Top view of a wall flame burner flame ring.

causes and remedies, which you will encounter when troubleshooting domestic-type oil burners are listed in chart 2. To make use of the listings, you must first determine what the trouble is. Then you can refer to the chart and find the cause and the remedy.

CHART 2

List of Common Troubles

Trouble	*Cause*	*Remedy*
1. Oil Failure.	*a.* Oil storage tank empty.	*a.* Refill.
	b. Nozzle clogged.	*b.* Remove the burner assembly. Clean or replace the nozzle.
	c. Strainer clogged.	*c.* Clean the line strainer, the fuel unit strainer, and/or the nozzle strainer.
	d. Internal bypass plug may not be in place when installing the burner with a return line.	*d.* Install the bypass plug.
	e. Restriction in suction line, other than clogged strainers.	*e.* Use a vacuum gage to check the line back to the tank. Use a bicycle pump, attached to the burner end of the line, to blow back any obstructions in the line.
	f. Vacuum leak in the suction line.	*f.* Locate and repair the leak. In extreme cases (*e* and *f*) it may be necessary to run a new suction line.
	g. Leaky pump shaft seal.	*g.* Replace the seal.
2. Motor failure.	*a.* Bypass plug installed in fuel unit when used with a single-pipe system, thereby building up excessive pressure and stalling the motor. May blow the fuses.	*a.* Remove the bypass plug. Check the fuel unit and the motor for possible damage.
	b. Motor starting switch dirty or sticking.	*b.* Remove the motor end bell and examine the switch assembly. If the remedy is not obvious, replace the switch assembly or change the motor.
	c. Motor condenser is burned out.	*c.* Short out the condenser. If the motor runs, replace the condenser.
	d. Motor is shorted or burned out.	*d.* Replace the motor with one of same rotation.
3. Ignition failure.	*a.* Transformer terminals are not connected.	*a.* Connect and properly tighten the terminals.
	b. Electrodes are not set properly.	*b.* Adjust the setting.
	c. Carbon on the electrodes.	*c.* Clean and check the setting.
	d. Weak transformer.	*d.* Replace transformer.
	e. Electrodes are cracked or grounded.	*e.* Replace the electrodes and adjust the setting.
4. Faulty control operation.	*a.* Stack control helix is badly sooted.	*a.* Remove the control and clean the helix with a small brush.
	b. Stack temperature is too low because the fire is too small for the heating load.	*b.* Increase the gph and adjust the fire for boiler size.
	c. Too frequent cycling of the thermostat.	*c.* Adjust thermostat for longer running cycles. Check wiring to thermostat heat anticipator.
5. Irregular stack temperature.	*a.* Change in draft.	*a.* Install the draft regulator.
	b. Downdraft caused by obstruction such as trees or insufficient chimney height.	*b.* Remove the obstruction. Increase the chimney height or install an H-hood.
	c. Bad draft due to leaks in the chimney.	*c.* Other openings should be closed.
	d. Fluctuating flame.	*d.* Check burner operation. Nozzle may be partially clogged or there may be water in the oil. Fuel unit pressure may be set too low so that the oil delivery is not uniform.
6. No electric current to burner circuit.	*a.* Fuse blown.	*a.* Replace the fuse, and determine what caused it to blow

Trouble	*Cause*	*Remedy*
	b. Difficulty with the power source.	*b.* Notify the electrician.
	c. Break in the wiring or bad connection.	*c.* Check it with test equipment and repair it.
	d. Defective controls.	*d.* Repair or replace.
7. Burner fails to shut off.	*a.* Controls improperly wired.	*a.* Rewire the controls.
	b. Thermostat out of calibration.	*b.* Calibrate the thermostat.
	c. Wires shorted out.	*c.* Check with the test equipment and repair.
8. Smoke, odor, and fumes.	*a.* Improper burner adjustment.	*a.* Check the air and oil adjustments.
	b. Bad draft creating pressure in the chamber.	*b.* Check the overfire draft with the gage and correct.
	c. Air cone burned away or fallen out.	*c.* Check the air cone on the end of the blast tube. Correct or replace it.
9. Burner puffs when starting.	*a.* Electrode is not properly set.	*a.* Reset the electrodes.
	b. Weak spark due to a ground in the burner assembly.	*b.* Check and correct.
	c. Weak spark, or no spark at all.	*c.* Check out the transformer and replace it if necessary.
10. Burner short cycling.	*a.* Limit control is cutting off and on.	*a.* Check the wiring and location of the limit control; also check the thermostat.
	b. Thermostat differential is set to close.	*b.* Adjust for wider differential.
11. Improper flames.	*a.* Oil pressure too high or too low.	*a.* Adjust the fuel pump for 100 pounds of pressure. Set the air shutter for the proper smoke reading.
	b. Poor draft.	*b.* Check the chimney and smokepipe.
	c. Improper adjustment of the burner air shutter.	*c.* Adjust to produce an orange flame with no chimney smoke and no more excess air than necessary.
12. Burner noisy.	*a.* Motor drive coupling is loose or worn.	*a.* Replace the worn parts. Check the alinement.
	b. Rigid electric or oil pipe connections at the burner.	*b.* Relieve the strain by installing flexible sections at the burner.
	c. Fuel unit is not reassembled properly.	*c.* Reassemble the fuel pump.
	d. Tank hum.	*d.* Install an antihum diaphragm.
13. Excess fuel consumption.	*a.* Poor atomization.	*a.* Adjust to the proper flame.
	b. Excessive draft.	*b.* Readjust for a −0.02-inch overfire draft.
	c. Low CO_2 (high excess air).	*c.* Eliminate the air leaks in the furnace or boiler. Adjust the draft and improve the flame.
	d. Fire is too small for the boiler or furnace.	*d.* Increase to the proper gph.
	e. Fire too large for boiler or furnace.	*e.* Decrease fire to proper gph.
	f. Improper setting of controls.	*f.* Check and reset the controls.
	g. Heat exchanger areas caked with carbon and slag.	*g.* Clean heat exchanger areas.
14. Excessive electrical consumption.	*a.* Fire may be set so low that burner operates continuously to heat the building.	*a.* Increase the gph to proper size.
	b. Bad adjustment, low CO_2.	*b.* Adjust burner for proper CO_2.

17-24. **Maintaining Domestic Oil Burners.** Some of the common services that should be accomplished on domestic oil burners are listed in the following paragraphs. These services should be scheduled and performed at the intervals recommended by the manufacturer of the oil burner. It is necessary for you to remove soot and carbon deposits from the nozzle. A nozzle is a delicate unit and should be handled with care. Use safety solvent to clean the nozzle. Compressed air also can be used for cleaning; however, goggles should be used to protect your eyes. Also, clean the fuel lines, storage supply tanks, strainers, pressure regulator valves, and fuel pumps. Check all electrical wiring. Lubricate electric motors and other units requiring lubrication, being careful not to overoil. When you clean soot from the firebox, refractories, flues, and chimney, you should follow the manufacturer's instructions. You have been studying the construction, operation, and care of domestic oil burners. Now you are going to study similar discussions with regard to commercial oil burners.

18. Commercial Oil Burners

18-1. There are many different types of commercial oil burners. Some of them are enlarged units of the domestic type, whereas others are small industrial models. Some burners, with slight modifications, can be used in domestic as well as commercial and industrial heating systems.

18-2. Horizontal rotary oil burners, originally designed for commercial and industrial use, also are currently available in sizes for use in domestic installations. There are two types of horizontal rotary oil burners. One type rotates the atomizer or cup with an electric motor, while the other type rotates the atomizer by means of an air turbine.

18-3. Figure 83 illustrates a horizontal rotary oil burner driven by an electric motor. In this burner assembly the oil flows from a hollow shaft into a rapidly rotating atomizer, from which it is atomized by centrifugal force. Air is forced through the vanes of the fan surrounding the atomizing cup. This shapes the flame and mixes the air with the oil. The turbine-driven oil burner is designed so that part of the air is forced through the turbine. The turbine rotates the atomizer which shapes the oil spray pattern.

18-4. Horizontal rotary oil burners are usually constructed to swing away from the firebox to facilitate inspection and cleaning. They operate satisfactorily within a wide range of fuel oils. The larger units are able to atomize and burn very heavy oils.

18-5. The installation, operation, troubleshooting, and preventive maintenance procedures are basically the same as those listed for domestic-type oil burners. There will be certain specific variations in these procedures; consequently, always refer to the recommendations of the manufacturer for definite procedures.

19. Industrial Oil Burners

19-1. Oil burners and equipment for industrial use are usually designed to burn lower cost, heavy fuel oils such as U.S. Commercial Standard Grades Nr 4, Nr 5, and Nr 6. The viscosities of these oils are much greater than those of the lighter domestic grades. For this reason the equipment required for satisfactory storage, pumping, and combustion differs considerably from that used in most domestic oil-burning systems.

19-2. **Horizontal Rotary Burners.** This type of oil burner is similar to the horizontal rotary burner described for commercial heating, only much larger. The rotary cup burner has been the

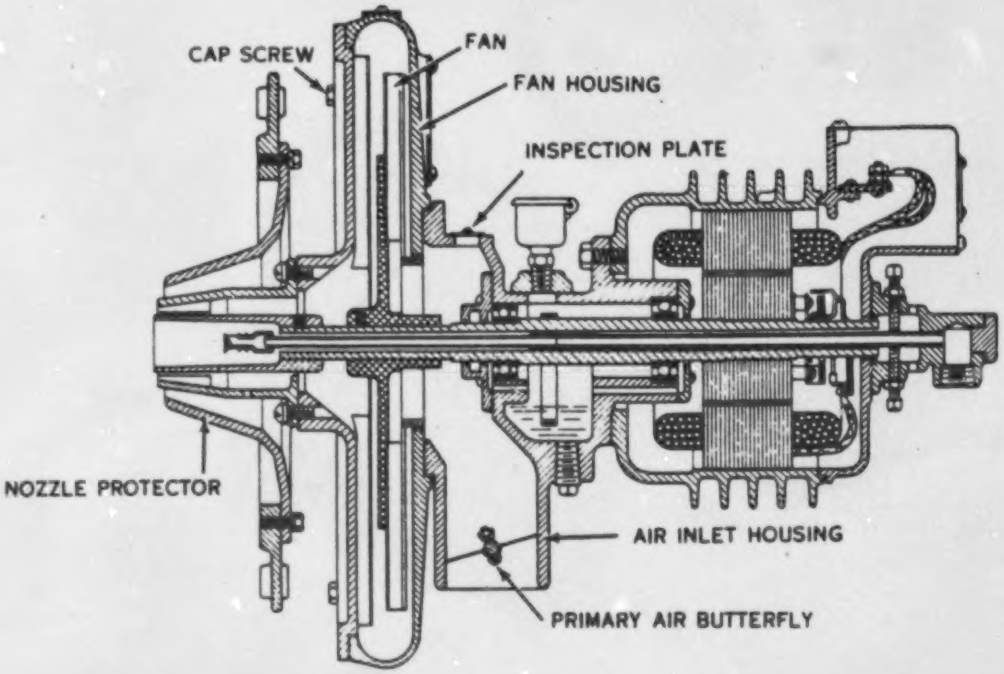


Figure 83. A horizontal rotary oil burner.

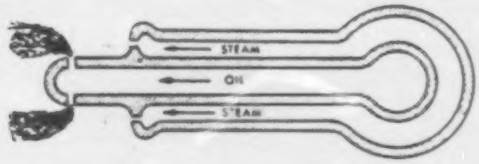


Figure 84. The cross section of an outside-mix oil burner nozzle.

most popular in the capacity range of 25- to 500-boiler horsepower. Its principal advantages are that it is a self-contained integral unit; it is adaptable for manual, semiautomatic, and fully automatic control; and its firing rate can be easily varied through a wide range while maintaining high efficiency.

19-3. **Steam-Atomizing Burners.** Steam-atomizing oil burners are the most common of any of the nonmechanical types of oil burners and require only a minimum amount of equipment. The oil is supplied at pressures of from 5 to 30 psi. and steam is available from the boiler itself. The steam used by an oil burner of this type is usually less than two percent of the boiler output. These burners may be divided into two general groups, the outside-mix type and the inside-mix type.

19-4. *Outside-mix type.* A burner of the outside-mix type uses a nozzle similar to the one illustrated in figure 84. Air for combustion is produced by natural draft. The units equipped with this type of burner will operate at a high rate of efficiency only when limited to moderate capacities without side fluctuations. It is not adapted to fully automatic operation or to wide variations in firing rate. This burner is relatively low in initial cost.

19-5. *Inside-mix type.* The inside-mix oil burner normally produces a flat or conical flame, depending upon the type of nozzle used. For an oil burner subjected to wide fluctuations or extreme loads, a nozzle similar to the one in figure 85 is used. The installation, operation, troubleshooting, and preventive maintenance procedures used for industrial oil burners should be procured from the manufacturer of the oil burner.

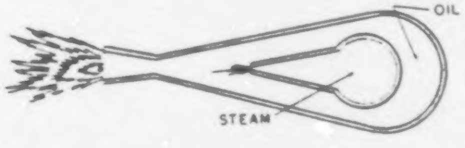


Figure 85. The cross section of an inside-mix oil burner nozzle.

20. Conversion Oil Burners

20-1. Conversion oil burners are installed in furnaces and boilers where there is a need to change to fuel oil from the fuel that is currently being used. It is necessary to determine the heating load before selecting the proper size of burner for a furnace or a boiler. Most furnace manufacturers rate their furnaces by the square inch area of the duct that is to be connected to the furnace. When you wish to determine the size of the nozzle you multiply this area by 0.0025. The resulting figure is the amount of oil to be burned per hour. For example, if you have a duct area of 500 square inches, a 1.25-gph nozzle should be used.

20-2. Steam boiler manufacturers rate their boilers by equivalent direct radiation (edr) instead of by duct area. To determine the size of the nozzle for steam boiler operation, you figure the amount of radiation for each radiator, add the total, and then divide this by 300. The answer is the amount of oil that will be burned per hour.

20-3. All conversion oil burners should be installed in accordance with the manufacturers' instructions and in compliance with local base directives.

20-4. In these previous paragraphs you have studied about the various types of oil burners, their uses and operation, and about troubleshooting them. Your next assignment here is to study how these burners are controlled.

21. Oil Burner Controls

21-1. The purpose of oil burner controls is to provide automatic, safe, and convenient operation of oil burners. The system is designed to maintain the desired room temperature, to start the burner as required, and to ignite the oil to initiate combustion. However, in case trouble arises during operation, the burner must be stopped and further operation prevented until the trouble has been corrected.

21-2. Controls for oil burners are essentially the same as stoker and gas controls. The only difference is that the oil burner has, in addition, two ignition electrodes and a primary or safety ignition control. A diagram of a typical gravity warm-air control system is shown in figure 86.

21-3. A pressure limit control is required for steam boiler operation, whereas a temperature limit control is required for warm-air furnaces to stop the burner in case of excess pressure or temperature. Additional safety devices can be furnished by the manufacturer to suit the type of burner, as required.

21-4. **Ignition Electrodes.** The fuel oil is ignited by the heat of a spark jumping between two ignition electrodes. The gap between the elec-

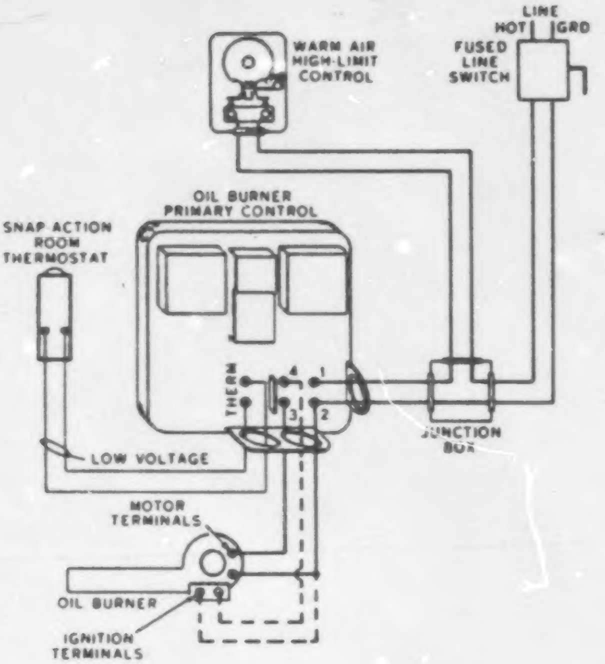

LINE
HOT
GRD
FUSED LINE SWITCH
WARM AIR HIGH-LIMIT CONTROL
OIL BURNER PRIMARY CONTROL
SNAP ACTION ROOM THERMOSTAT
THERM
4
1
3
2
JUNCTION BOX
LOW VOLTAGE
MOTOR TERMINALS
OIL BURNER
IGNITION TERMINALS

Figure 86. Typical gravity warm-air control system.

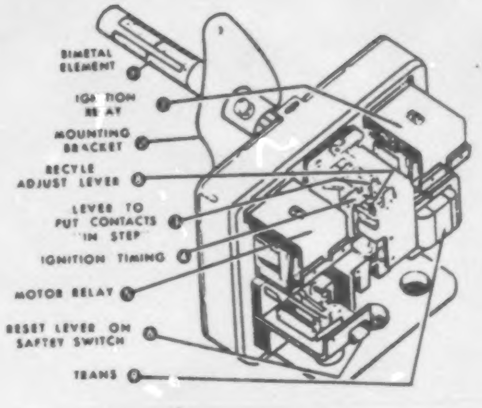

BIMETAL ELEMENT
IGNITION RELAY
MOUNTING BRACKET
RECYLE ADJUST LEVER
LEVER TO PUT CONTACTS "IN STEP"
IGNITION TIMING
MOTOR RELAY
RESET LEVER ON SAFTEY SWITCH
TRANS

Figure 87. An interior view of a primary control.

trodes is from ⅛ inch or as otherwise specified. Each manufacturer will prescribe the correct gap setting. The voltage necessary to cause the spark to jump is much more than the line voltage available. Therefore, an electric transformer is used to step up the line voltage to approximately 10,000 volts.

21-5. **Primary Control.** The burner primary control is electrically connected between the thermostat and the burner, as illustrated in figure 86, and performs several functions. The primary control closes the motor and ignition circuits when the thermostat calls for heat. It breaks the motor circuit and stops the burner when the burner motor first starts and the fuel oil fails to ignite; also during or after burning if the flame fails. The control prevents the starting of the burner in case of electrical failure, until all safety devices are in a normal starting position.

21-6. An interior view of the primary control of the oil burner is shown in figure 87. The control is equipped with a sensing device which responds to the temperature of the flue gases and thus breaks the electrical circuits if some malfunction exists in the burner control system.

21-7. **Thermostat.** The thermostat used for oil burners is similar to the thermostat used with stokers and gas-burning systems. However, a special double-contact thermostat which controls three stages of firing can be used for oil burners. When the room temperature is in the range between the two contacts, the burner is at medium fire; when below, at high fire; and when above, at pilot fire.

21-8. **Burner Control Maintenance.** Once each year the contact points of the individual control units should be cleaned and all electrical contacts tightened. If trouble is experienced with any of the units, you should consult the manufacturer's service manual for making adjustments and repairs. As a general rule, oil burner controls are quite trouble-free.

77

CHAPTER 6

Gas Burners and Controls

THROUGH the years houses and other buildings have become more luxurious, and better standards of living and working have been realized. The need for a fuel that could be controlled automatically and would burn cleanly, without the offensive dust and odors of coal and oil, became great. Through the discovery and extensive use of natural gas and liquefied petroleum gas this need has been satisfied temporarily. Now we are looking forward to atomic power for heating.

2. In three previous chapters of this Memorandum coal-burning and oil-burning heating equipment were discussed, and some major advantages and disadvantages of this equipment were given. This chapter will give similar information about gas-burning equipment. The discussions here will include information about gas pressure systems, types of gas burners, measuring gas pressure, maintenance of gas burners and conversion burners. You will find that the use of this type of equipment makes your work as a heating systems specialist much easier to accomplish.

Natural gas is a nearly ideal fuel because it burns easily, requires comparatively simple equipment and labor, is almost free of noncombustibles, and is clean. It is a comparatively dangerous fuel, however, because it mixes easily with air and burns readily. Extreme care must be exercised to prevent or stop any leakage of the gas into an unlighted furnace or into the boilerroom. All gas burners should be approved by the American Gas Association and installed in accordance with applicable standards of the National Board of Fire Underwriters.

Gas line pressures vary widely and are usually transmitted at pressures too high to be used in a heating unit without reduction. These high pressures are generally reduced to a pressure varying from a few ounces to approximately 30 pounds per square inch (psi), depending upon the type and size of the burner used. The reduction in pressure is accomplished by using a diaphragm reducing valve which, when once adjusted, will maintain a fixed pressure to the burner as long as the main line pressure remains above the set pressure of the reducing valve.

After the gas is reduced to the proper pressure at the reducing valve, it is forced out of an orifice or tip called a "spud." The gas and air are mixed and burned. Air may be supplied to the burner at atmospheric pressure, or the burner may be incased in a duct and the air supplied to it under pressure by a blower.

Gas burners should always be equipped with safety pilots ("Flame Rods," "Protect O Glow," or some other system) which insure lighting. The pilot is a flame or igniting device that starts the main burner. If the pilot fails, gas is not admitted to the burners. When the pilot flame is extinguished, you must purge and ventilate the furnace before lighting it again.

If propane or butane gas is used, be sure to ventilate the furnace each time it is fired. Propane and butane gases are heavier than air and extra time is required for diffusion and removal of accumulated gas pockets. These gases tend to settle in the bottom of the firebox or the combustion chamber.

22. Gas Pressure Systems

22-1. Usually gas-burning systems are classified according to the amount of gas pressure each one utilizes. These are classed as low-pressure and high-pressure systems.

22-2. The low-pressure systems are designed for relatively low capacities, and they operate with the natural gas at pressures of 2 ounces to 3 psi. A multijet burner is employed to provide maximum heat from the gas and air at the pressure available. The gas is conveyed to several burner units from a manifold which in installed between the supply line and the burners. The manifold must be used when several burners are operating in one unit.

22-3. The high-pressure burner operates on pressures of 2 to 25 psi. Because the pressure in a gas main, serving a large plant, can vary as much as 30 to 50 psi, the high-pressure is reduced and maintained by means of a pressure-reducing valve. With the high-pressure systems, the air for combustion is normally supplied under pressure by means of a blower.

85

23. Measuring Gas Pressure

23-1. Since a burner may be designed for a specific pressure, it is necessary to set gas pressure at a certain number of pounds per square inch. Also, it is more economical to use gas at a low pressure, providing the heating unit will produce maximum heat. Usually, the gas pressure can be adjusted at the pressure regulator. Various vacuum and pressure gages are used to determine gas pressure. The most important and commonly used gages are the Bourdon pressure gage and the manometer.

23-2. **Bourdon Gage.** The essential element of the Bourdon gage is an oval metal tube, curved along its entire length to form almost a complete circle. One end is closed and the other end is connected to the source of pressure to be measured. The application of pressure to the tube tends to straighten it. This movement is transmitted by linkages to a needle moving over a gradual dial. The dial is calibrated, or scaled, to read directly in pounds per square inch.

23-3. **Manometer.** Another instrument that is used to measure pressure and vacuum for gas burners is called a manometer. It is a U-shaped glass tube 30 inches long on each leg and half filled with water or mercury, as shown in figure 88. In detail B of figure 88, the manometer is at a neutral stage; that is, the pressure on both legs is equal. Illustration A shows a manometer connected to a gas pressure line and indicates a pressure differential of four inches. Illustration C shows the instrument connected to a vacuum line indicating a vacuum differential of 4 inches. This static pressure is referred to as inches of water or mercury, depending on the type of liquid used in the manometer tube. Although the pressure is read in inches of water or mercury, it may also be expressed in ounces or pounds per square inch. You have now studied how gas pressure is furnished to the heating plant and how this pressure is measured. We will next discuss the types of burners that use gas.

24. Types of Gas Burners

24-1. The natural gas burners that are used in heating appliances usually have a nonluminous flame and are the Bunsen-type burner that is illustrated in figure 89. Part of the air needed for combustion is primary air that is drawn into the burner mixing tube or venturi, where it mixes with the gas and is burned at the burner ports. The secondary air is supplied around the base of each separate burner flame by natural draft or is induced by a draft fan.

24-2. **Bunsen.** Bunsen gas burners are designed in many different sizes and shapes, some of which are illustrated in figure 90. The burner design is determined largely by the shape of the combustion chamber in the heating unit, the firebox, and the method used for mixing the air with the gas. All of the burners illustrated in figure 90 are usually considered to be the low-pressure type.

24-3. **Radiant.** Radiant gas burners are horizontal firing, usually through a large number of small orifices or spuds. These orifices inject and control a stream of gas through hollow refractory blocks which have a number of openings, in the form of various designs, in the front or heating side. The flames burn directly in the hollow refractory blocks and extend almost the full length of the blocks, depending upon the amount of gas passing through the orifice.

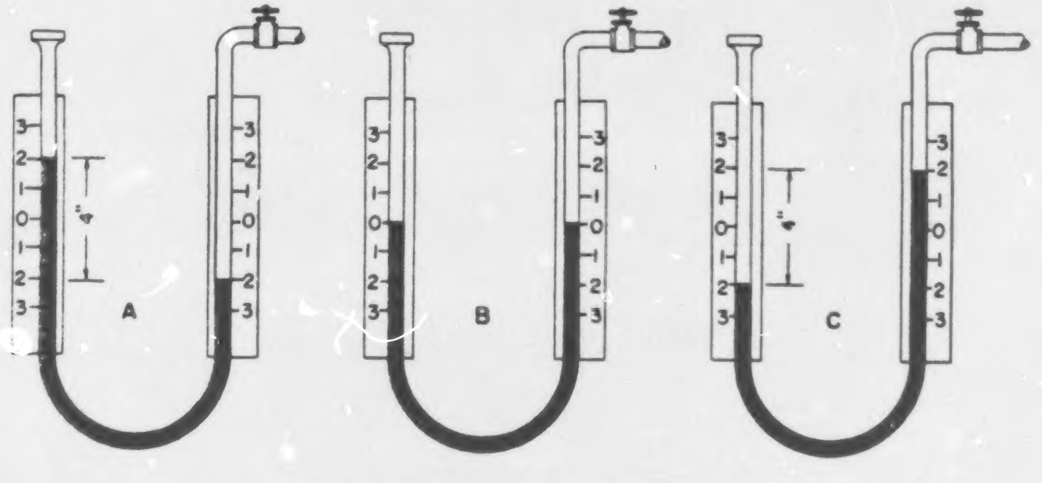


Figure 88. Open manometers having different readings.

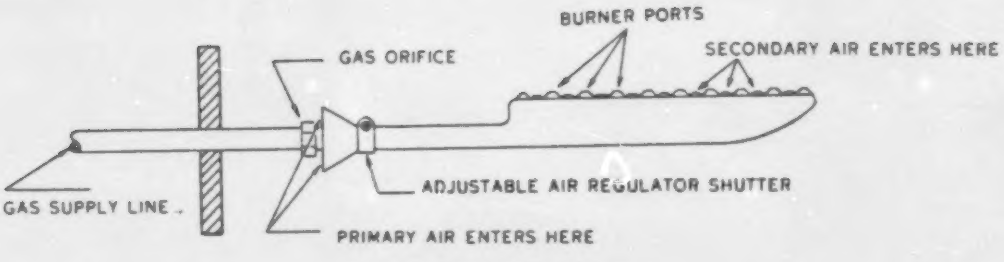

BURNER PORTS
GAS ORIFICE
SECONDARY AIR ENTERS HERE
ADJUSTABLE AIR REGULATOR SHUTTER
GAS SUPPLY LINE
PRIMARY AIR ENTERS HERE

Figure 89. The Bunsen-type burner.

24-4. Open brick baffles are sometimes located directly behind the burners at about two-thirds normal flame height. These baffles are built so that the front area is completely open, requiring the flame to pass through the baffles close to a very hot refractory surface. The pilot lights are usually placed in the center of the row or orifices.

24-5. **Upshot.** Upshot or vertical gas burners are usually built in units. Each unit is composed of a venturi or mixing throat that is mounted directly over an orifice or spud in the manifold, as illustrated in figure 91. The burner top surfaces vary widely in design. Some have drilled or slotted tops; others have a brick or refractory mounted on a grid or slotted spacer. In each type, however, the gas-air mixture must pass through a small port before it is ignited, thus offering protection against flashback. Burners of this type are not readily converted to oil use for standby operation.

24-6. **Inshot.** Inshot gas burners are usually the horizontal type. A typical inshot gas burner is illustrated in figure 92. These burners are similar in construction to the upshot type. The advantage of this type of burner is that it can be installed in the lowest part of the furnace firebox. This greatly increases the prime heating surface exposed to the flame and causes the maximum amount of heat to be extracted from the fuel being burned. These burners are also easier to install in an existing fire-

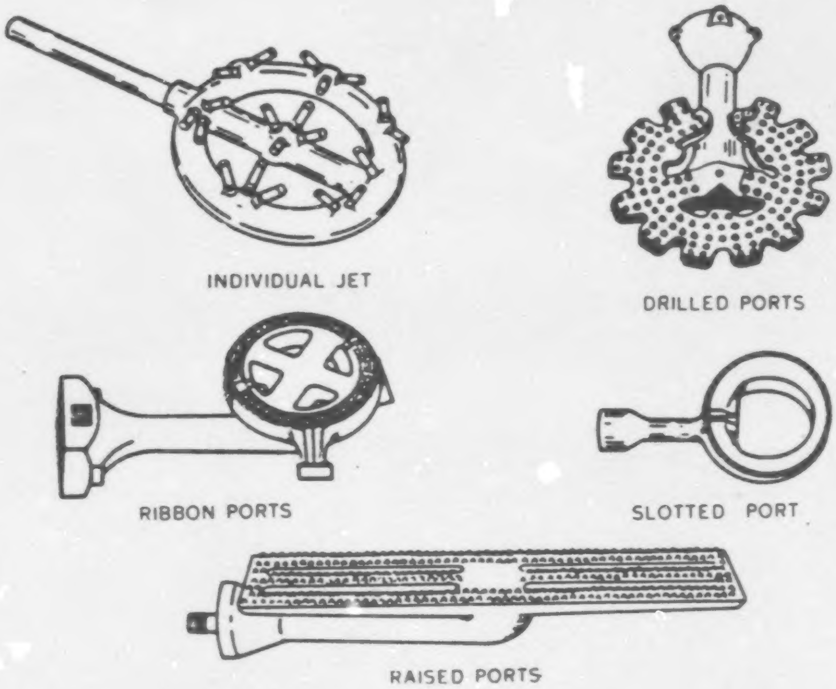

INDIVIDUAL JET
DRILLED PORTS
RIBBON PORTS
SLOTTED PORT
RAISED PORTS

Figure 90. Typical Bunsen gas burners.

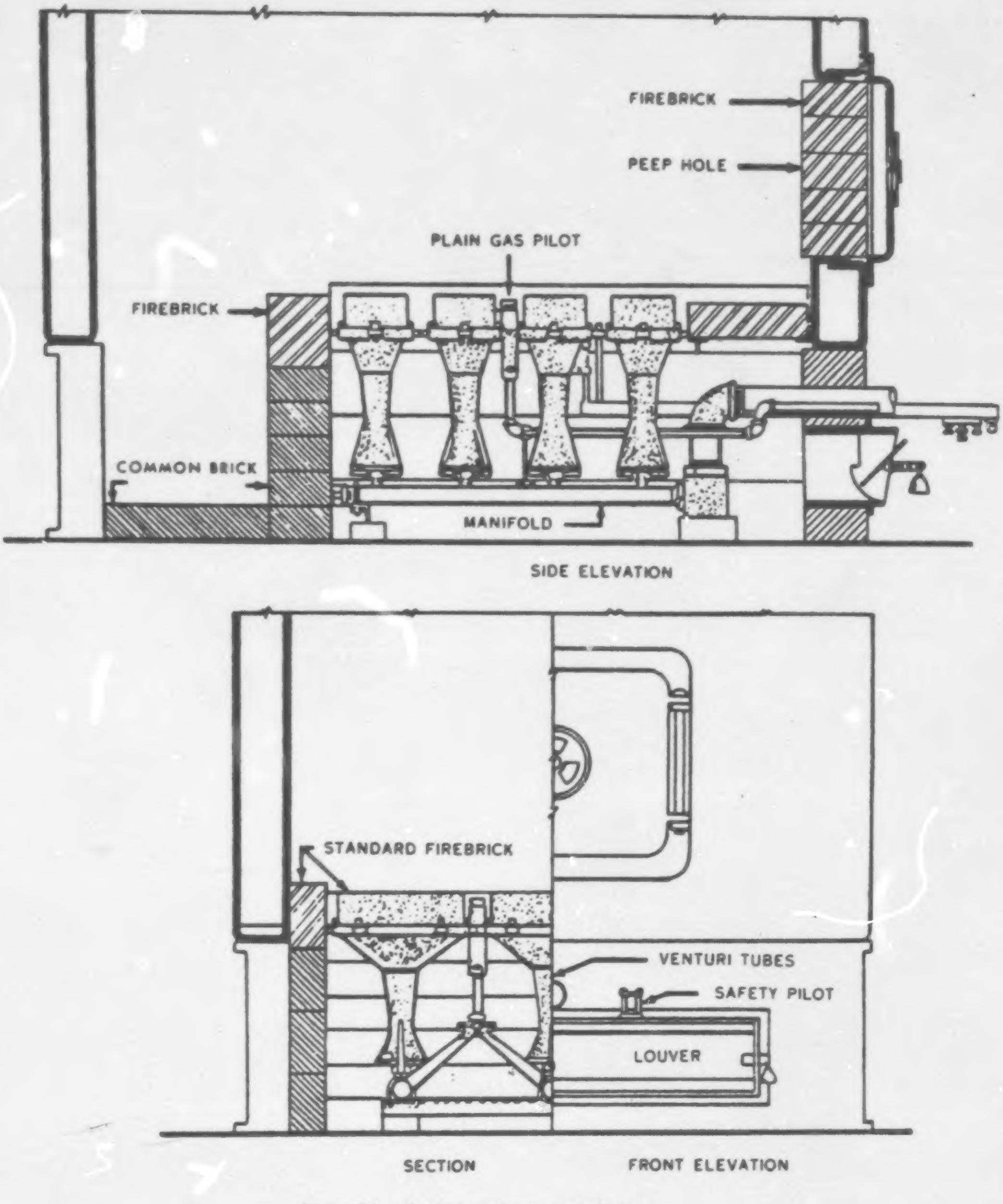

FIREBRICK
PEEP HOLE
PLAIN GAS PILOT
FIREBRICK
COMMON BRICK
MANIFOLD
SIDE ELEVATION
STANDARD FIREBRICK
VENTURI TUBES
SAFETY PILOT
LOUVER
SECTION
FRONT ELEVATION

Figure 91. Upshot gas burner installation.

box, since their construction makes them a small and compact unit.

24-7. **Premix.** Premix gas burners are equipped with an electric motor and blower that is used to compress the air and mix it with gas at the same time. An illustration of a typical premix gas burner is shown in figure 93. Burners of this type operate satisfactorily in combustion chambers which do not have good refractory surfaces. They are, therefore, well adapted to Scotch marine boilers, because these burners are not usually adaptable for conversion to oil burning.

24-8. **Combination Gas and Oil.** Combination gas and oil burners are used for the purpose of firing two different types of fuels. This does not mean that both types of fuel are burned at the

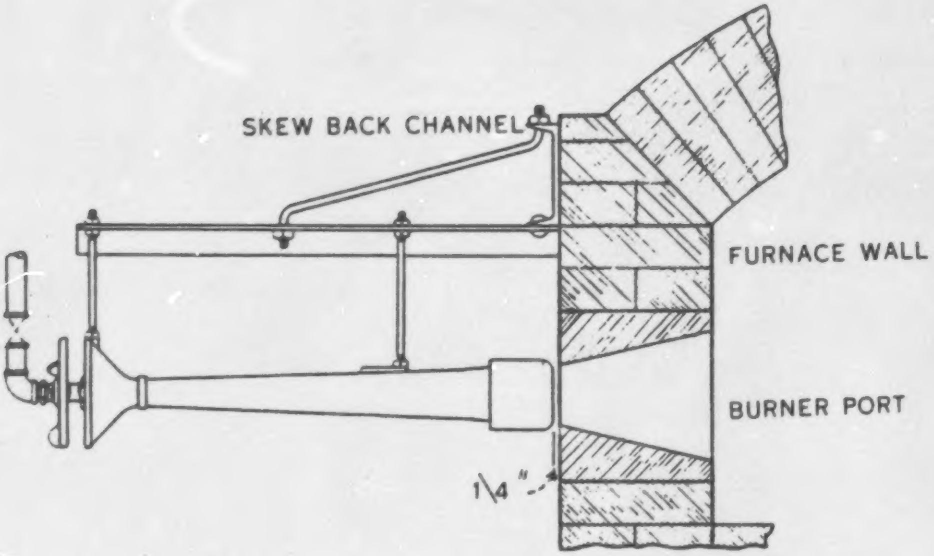


Figure 92. An inshot gas burner.

same time. Usually, the fuel that is the most abundant or the cheapest is used during production hours, while the other fuel may be provided for standby operation.

24-9. Combination gas and oil burners are usually round in design as illustrated in figure 94. The complete burner can be mounted either in the front or rear of the combustion chamber of the heating unit. Both gas or oil burners are connected with unions or flexible tubing, so that the burners can be removed or changed easily. All gas burners, regardless of the types, should be approved by the American Gas Association and installed in accordance with applicable standards of the National Board of Fire Underwriters.

24-10. **Liquefied Petroleum Gas.** The Bunsen-type burner used with natural gas is also the principal gas burner used with liquefied petroleum gases (L.P.G.). The liquefied petroleum gas-heating units have smaller combustion chambers, and the burners of these units have smaller orifices than do the natural gas units. The normal gas pressure for liquefied petroleum gases is slightly higher than for natural gas. The L.P.G. burners require 100 percent cutoff safety pilots.

25. Maintenance of Gas Burners

25-1. Gas burners should be inspected to note the appearance of the gas flame. A yellow flame indicates a poor air-fuel mixture and that carbon is being formed as the result of incomplete combustion. Such formations indicate poor flame adjustment. This carbon must be kept removed, so frequent cleaning of the unit is necessary. You should inspect the burner orifices and correct any condition which restricts the gas flow or changes the direction of gas flow. Also examine the interior of the combustion chamber and the passages in the heating unit for soot and carbon formation. There should be no formation of soot when burning the gas completely.

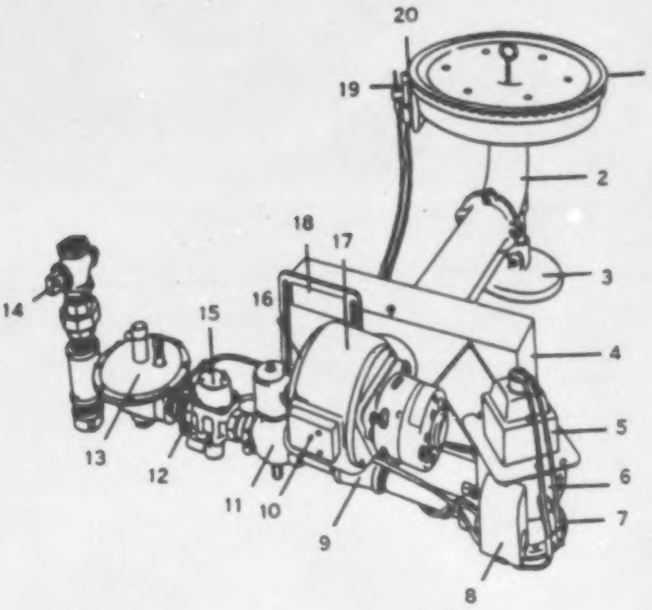
25-2. Now that you have studied the different types of gas burners and the maintenance of these burners, it is logical to discuss the gas burner feed assembly.

26. Burner Feed Assembly

26-1. A gas burner assembly usually includes the following units: manual gas valve, gas pressure regulator, some type of automatic gas valve, pilot light, thermocouple, relay, and limit control. A main gas cock must be installed ahead of the burner assembly.

26-2. **Standard Solenoid Valve.** The manual gas valve on a heating unit is usually installed next to the gas pressure regulator. It is used to shut off the gas to the heating unit in case some of the controls are being repaired or replaced.

26-3. **Pressure Regulator.** The gas pressure regulators used in domestic gas-heating systems are usually of the diaphragm type, like the one illustrated in figure 95. This gas pressure regulator maintains the desired pressure in the burner as long as the gas main pressure is above the desired pressure. The pressure spring holds the piston down off its seat when the gas pressure in the



1. Burner Head
2. Venturi
3. Burner Leg
4. Adjustable Front
5. Transformer
6. Conduit Box
7. Mercury Blower Switch
8. Junction Box
9. Gas Metering Valve
10. Air Safety Switch
11. Automatic Gas Valve
12. Manual Pilot Valve
13. Pressure Regulator
14. Main Gas Valve
15. Safety Shut-Off
16. Air Shutter
17. Combustion Blower
18. Burner Door
19. Thermocouple
20. Gas Pilot

Figure 93. A premix gas burner.

burner is low. A gas pressure above the desired amount will force the diaphragm up. This allows the piston spring to reseat the piston and stop the gas flow until the pressure in the burner drops. The regulator is thus closed every time the burner pressure gets above the desired amount. The setting of the regulator can be varied by turning the adjusting screw located at the top of it.

26-4. **Solenoid Gas Valve.** The basic principles of construction and operation applied in all solenoid gas valves are similar. However, the design of each individual unit differs somewhat from the others. The two most common types of solenoid gas valves are the standard solenoid valve and the recycling solenoid valve discussed in the following paragraphs.

26-5. *Standard solenoid valve.* The standard solenoid gas valve shown in figure 96 is of the electric type. It is suitable for use with gas furnaces, steam and hot water boilers, conversion burners, and industrial furnaces. This valve operates when a thermostat, limit control, or other device closes a circuit to energize a coil. The energized coil operates a plunger, causing the valve to open. When there is a current failure, the valve automatically closes, causing the gas pressure in the line to hold the valve disc upon its seat. To open this valve during current failure, it is necessary to use the manual opening device at the bottom of the valve. When electric power is resumed, you place the manual opening device in its former position.

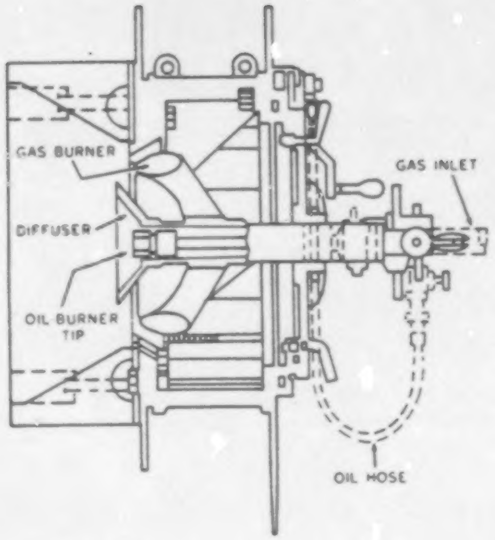

GAS BURNER
GAS INLET
DIFFUSER
OIL BURNER TIP
OIL HOSE

Figure 94. A combination gas and oil burner.

26-6. *Recycling solenoid valve.* The recycling solenoid gas valve illustrated in figure 97 can be used with the same heating equipment as the standard solenoid gas valve. The design of this valve differs from that of the standard solenoid gas valve in that it is equipped with an automatic recycling device which allows the valve to switch to manual operation during current failure. However, upon the resumption of the electric current, this valve automatically resumes control of the thermostat.

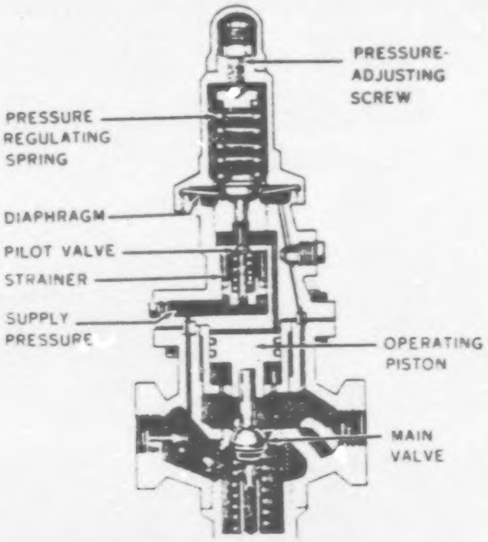

PRESSURE-ADJUSTING SCREW
PRESSURE REGULATING SPRING
DIAPHRAGM
PILOT VALVE
STRAINER
SUPPLY PRESSURE
OPERATING PISTON
MAIN VALVE

Figure 95. A gas pressure regulator.

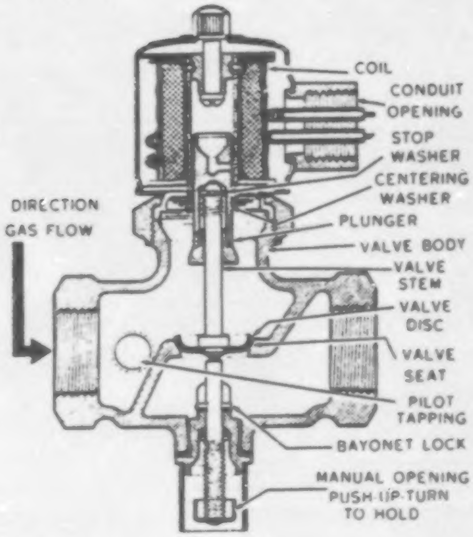

COIL
CONDUIT OPENING
STOP WASHER
CENTERING WASHER
DIRECTION GAS FLOW
PLUNGER
VALVE BODY
VALVE STEM
VALVE DISC
VALVE SEAT
PILOT TAPPING
BAYONET LOCK
MANUAL OPENING PUSH UP-TURN TO HOLD

Figure 96. A standard gas solenoid valve.

26-7. **Diaphragm Valve.** The diaphragm gas valve illustrated in figure 98 can be used interchangeably with a solenoid gas valve. Its main feature is the absence of valve noise when it is opening or closing. In this type of diaphragm valve the polarized relay energizes and opens the three-way valve, allowing the gas to flow out of the upper chamber of the unit. Reducing the pressure in the upper chamber in this manner causes the diaphragm to flex upward and open the gas valve. When the polarized relay is deenergized, the three-way pilot valve allows the gas to flow into the upper chamber, thus increasing the pressure and closing the gas valve.

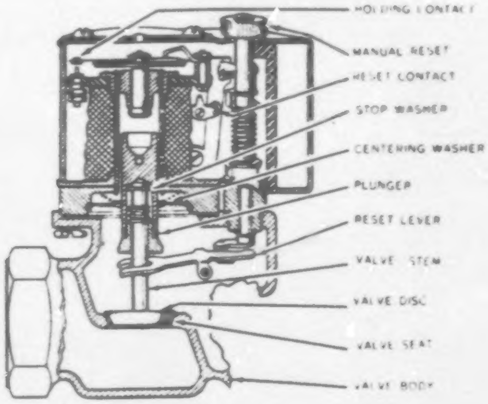

HOLDING CONTACT
MANUAL RESET
RESET CONTACT
STOP WASHER
CENTERING WASHER
PLUNGER
RESET LEVER
VALVE STEM
VALVE DISC
VALVE SEAT
VALVE BODY

Figure 97. A recycling solenoid valve.

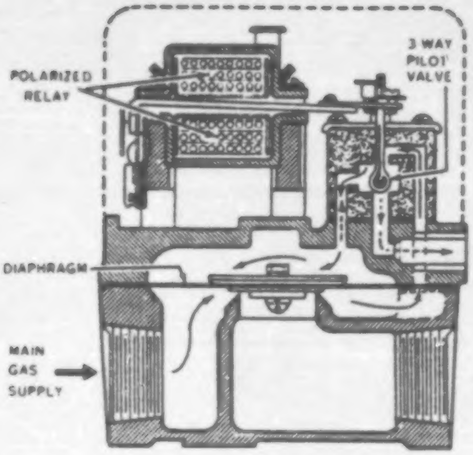


Figure 98. A diaphragm gas valve.

26-8. **Pilot Light.** The gas pilot light in a gas heating unit is a small continuous-burning flame that lights the main burner during normal operation of the heating unit. It is located near the main burner like the one shown in figure 93.

26-9. The gas flow to the pilot light is, in some cases, supplied by a small, manually-operated gas shutoff valve located on the main gas line above the main gas valve. In other cases, the gas can be supplied from the pilot tapping of a solenoid gas valve, as shown in figure 96. In more expensive heating units, the gas for the pilot light is often supplied by a thermocouple-controlled relay.

26-10. **Thermocouple.** A thermocouple is probably the simplest unit in the electrical field which is used to produce electric current by means of heat. It is constructed of two U-shaped conductors of unlike metals in the form of a circuit, as shown in figure 99. Suppose that these conductors were composed of copper and nickel, respectively, and joined as shown in the figure; then two junctions between the metals would exist. If one of these junctions were heated by a flame, a weak electric current would be produced in the circuit of these conductors. A series of junctions can be arranged to form a thermopile to increase the amount of current produced, as shown in figure 100.

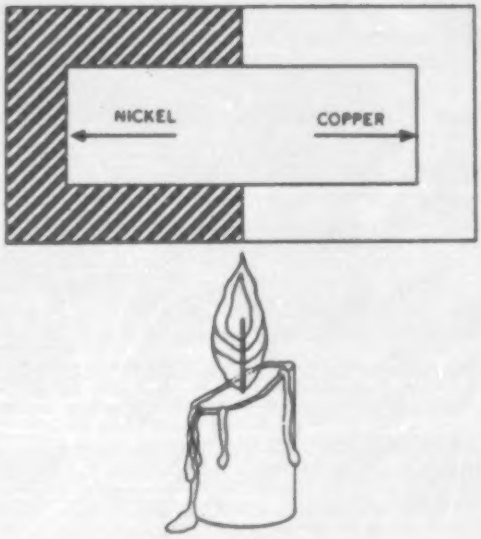


Figure 99. The principle of a thermocouple.

26-11. In the heating field, thermocouples and thermopiles are used to produce the electrical current used to operate such units as heating unit gas valves, relays, and other safety devices.

26-12. The thermocouple is located next to the pilot light of the main gas burner, as shown in figure 91. It generates the electric current which holds open a main gas valve, a relay, or any other safety devices permitting gas to flow to the main burner. Immediately after the pilot light is extenguished, current ceases to flow to these safety devices, thus causing them to shut off the gas to the heating unit. These safety devices will not operate again until the pilot light is lighted and current is again generated by the thermocouple.

26-13. **Thermocouple Control Relay.** The

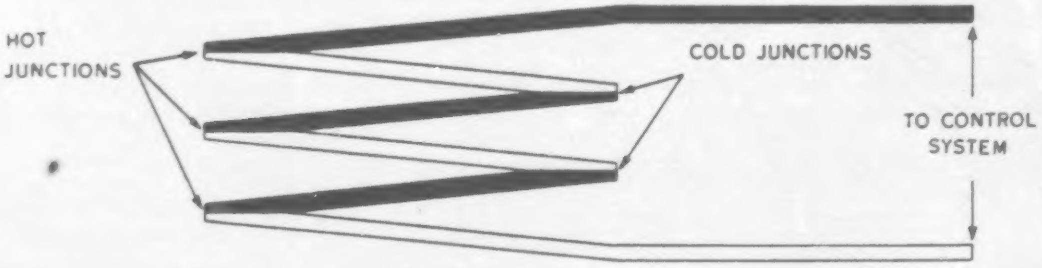


Figure 100. A thermopile.

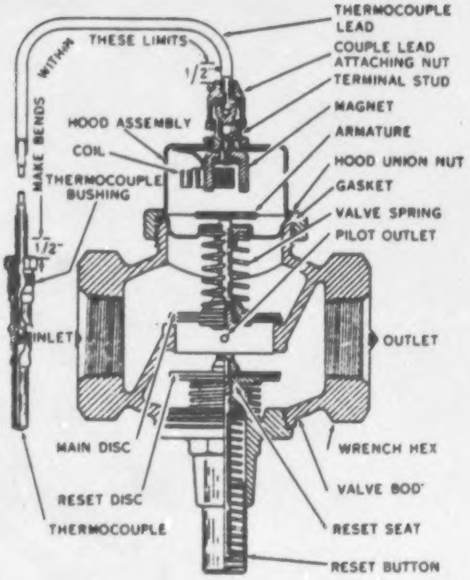

THERMOCOUPLE LEAD
THESE LIMITS
WITHIN
MAKE BENDS
1/2"
COUPLE LEAD ATTACHING NUT
TERMINAL STUD
MAGNET
HOOD ASSEMBLY
ARMATURE
COIL
HOOD UNION NUT
THERMOCOUPLE BUSHING
GASKET
VALVE SPRING
PILOT OUTLET
1/2"
INLET
OUTLET
MAIN DISC
WRENCH HEX
VALVE BODY
RESET DISC
RESET SEAT
THERMOCOUPLE
RESET BUTTON

Figure 101. A typical thermocouple and valve relay assembly.

thermocouple-operated relay, shown in figure 101, is a safety device used on gas-fired heating equipment. The thermocouple, when placed in the gas pilot flame, generates electricity. The electric current energizes an electromagnet that will hold a switch or valve in the open position as long as the pilot flame is burning. When the pilot flame goes out, because of high drafts or fuel failure, the electromagnet will be deenergized, thus closing and preventing the opening of the switch or valve. The closing of the valve or switch prevents the burner from filling the combustion chamber with unburned gases.

26-14. To relight the pilot light, it is necessary to push up the reset button at the bottom of the relay and allow the gas to flow to the pilot light. Since some heating units are not equipped with relays, the pilot light is not automatically shut off in case of gas supply failure.

26-15. The diagram illustrated in figure 102 is an electrical switch-type relay. It is entirely electrical and can be used as a controlling unit for either the magnetic or diaphragm gas valves. This unit is also actuated by the electric current generated by the thermocouple, and it controls the operation of the gas valve in the magnetic and diaphragm valves. A relay of this type must also be reset manually for normal operation.

26-16. **Limit Control.** The limit control in a gas burner system is a safety device. It shuts off the gas supply when the temperature inside the heating unit becomes excessive. The limit control device can be adjusted to the desired setting. It exercises direct control on the gas or diaphragm valve.

27. Burner Control Systems

27-1. Gas-fired burners can be equipped with any number or combination of manual as well as automatic control devices. The simplest control system available for a burner is one which is equipped with only one manual gas shutoff valve. A burner with a system of this type must be ignited when the gas shutoff valve is turned on. The use

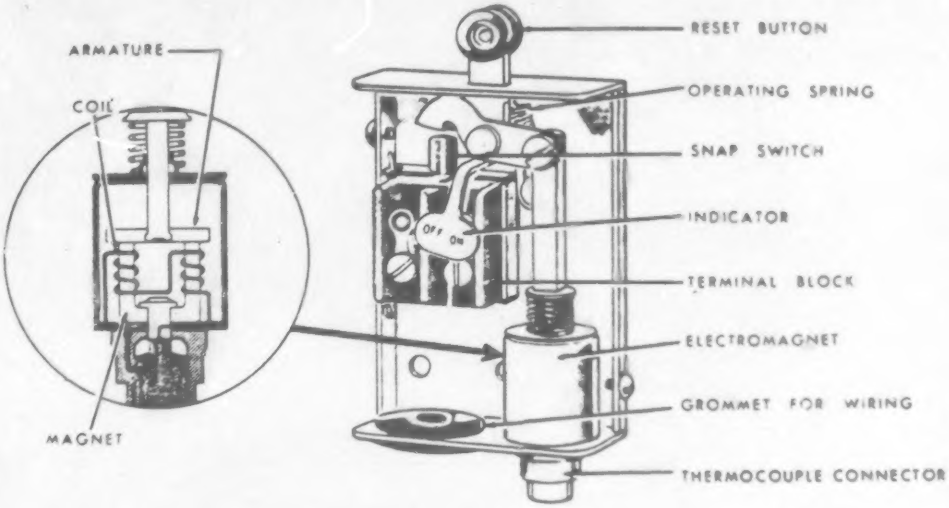

ARMATURE
COIL
MAGNET
RESET BUTTON
OPERATING SPRING
SNAP SWITCH
OFF
ON
INDICATOR
TERMINAL BLOCK
ELECTROMAGNET
GROMMET FOR WIRING
THERMOCOUPLE CONNECTOR

Figure 102. An electric switch-type relay.

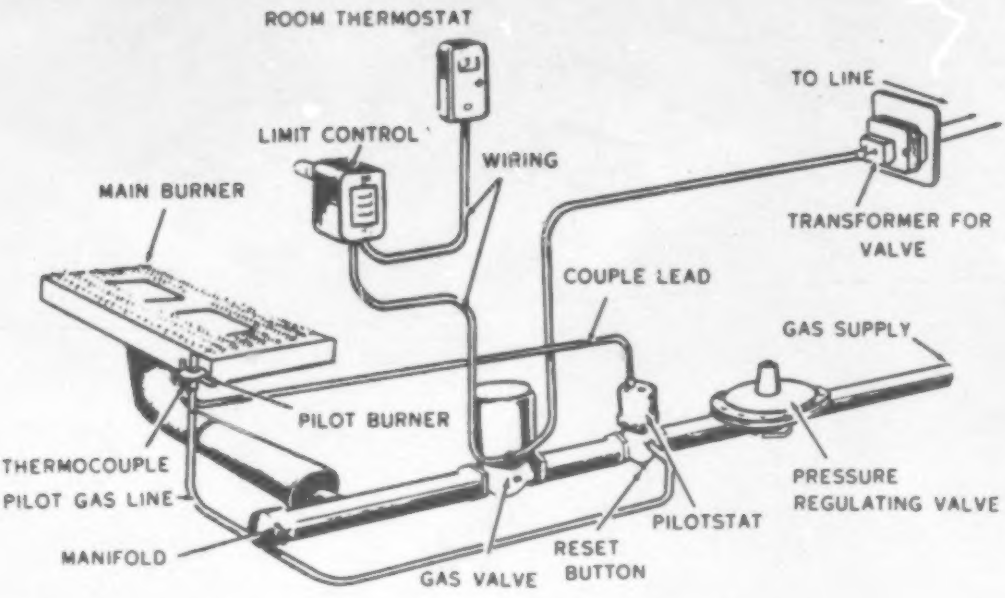


Figure 103. An automatic gas burner control system.

of this system is hazardous because of the escaping gas when the burner is accidentally extinguished.

27-2. Some burner control systems can be equipped with the same manual gas shutoff valve as the former system but with the added feature of a pilot light. A system of this type is much more convenient than the system with only the gas shutoff valve, because the pilot light, which burns continuosuly, is used to light the main burner when the gas shutoff valve is turned on. However, this system is just as hazardous as the system that does not use the pilot light.

27-3. Other burner systems employ the use of the pilot light, thermocouple, and some type of automatic gas valve to control the burner. When the pilot light in this system is extinguished, the automatic gas valve shuts off the gas flow to the main burner, but not to the pilot light. However, the gas valve will not open until the pilot light is ignited again. The escaping gas from the pilot light is assumed to be negligible and is carried away by the flue of the heating system. This system cannot be used with L.P. gas.

27-4. The more expensive gas burner systems use a combination control arrangement composed of a pilot light, pilotstat, thermocouple, and some type of automatic gas valve, as illustrated in figure 103. This system functions much like the system mentioned in the previous paragraph that does not use the pilotstat. The pilotstat is another added safety feature. Its purpose is to shut off the supply of gas to the pilot light as well as the main burner if the pilot light is extinguished. To relight the pilot, you must reset the reset button on the pilotstat.

27-5. The burner control systems mentioned are by no means the only types used; there are many more, but there is no need to discuss every type here.

27-6. Installation. The installation of gas burner controls will not be discussed in this Memorandum, because the control units mentioned in this chapter are installed by the manufacturer as part of the heating unit. Should installation procedures be required, the manufacturer of the unit will furnish them.

27-7. **Maintenance.** Gas burner control systems require very little attention. The maintenance that is required consists of removing and cleaning the pilot, burner, and thermocouple. You should check the system for gas leaks by using a soapsuds solution, and you adjust the primary air shutter of the burner, if necessary. Also tighten all wiring connections on the control units and clean the electrical contacts.

27-8. **Troubleshooting.** Either directly or indirectly, the pilot light is usually the cause of most inoperative gas burners. Improper positioning of the thermocouple or thermopile and excessive flue and chimney draft conditions account for the greater share of faulty pilot light troubles.

27-9. The pilot flame should be of sufficient length to heat the thermocouple and ignite the main burner without delay. It should be a blue color, without a yellow tip. A yellow flame indicates improper combustion, and it forms soot on the thermocouple to insulate it from the heat of the pilot light. A thermocouple must be kept clean, and the proper amount of heat must be supplied to it, to produce a sufficient amount of electricity to operate either a pilotstat or a gas valve. Excessive flue draft draws the pilot flame away from the thermocouple. This condition then causes improper heating of the thermocouple. Also, a short pilot flame will not heat the thermocouple sufficiently for the thermocouple to produce a current.

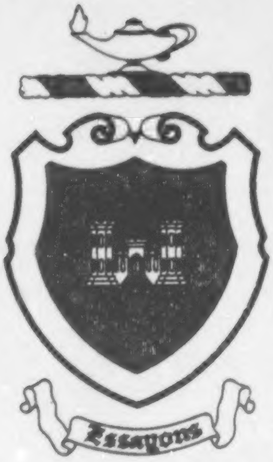
27-10. When the thermocouple operates properly, the trouble can be in the pilotstat or gas valve. These valves should be checked for poor electrical connections, as well as improper operation of the energizing electrical coils. In some cases, it is necessary to clean the valve seats, plungers, and plunger tubes in the solenoid gas valves. Since these valves are expensive, extreme care should be taken to avoid damage to the internal mechanism.

27-11. The limit control as well as the thermostat should be checked for proper operation. The proper attention should be given to the condition of all wiring. You should check the main gas valve for open position. If the fuel supply is suspected, you should use a manometer to check the gas pressure, then adjust the pressure regulator, if necessary.

28. Conversion Units

The installation of conversion gas burners is very similar to the installation of conversion oil burners covered in Chapter 5 of this Memorandum. However, the installation instructions furnished by the individual conversion gas burner manufacturer should be followed when making the installation of one of these burners.

ENGINEER
SUBCOURSE 565-1



HEATING AND VENTILATING II

(FUNDAMENTALS OF HEATING)

11-3

CORRESPONDENCE COURSE PROGRAM
U. S. ARMY ENGINEER SCHOOL
FORT BELVOIR, VIRGINIA

MOS: 51J20

EDITION 1 (NRI 112)

INTRODUCTION

This is the second of four subcourses on heating. Subcourse 564 introduced you to the subject by a discussion of such topics as blueprints, tools, piping, electricity, and insulation. This present subcourse develops the subject further by instruction on the theory of heat transfer, combustion, fuels, and the operation, installation, and maintenance of space heaters, furnaces, boilers, stokers, and oil and gas burners.

The subcourse consists of five lessons and an examination as follows:

Lesson 1. Principles of Heating.
2. Fuel and Fuel Systems.
3. Heating Unit Installation.
4. Coal-fired Furnaces and Stokers.
5. Oil and Gas Burners and Controls.

Examination.

Thirteen credit hours are allowed. You will not be limited as to the number of hours that you may spend on the subcourse, any lesson, or the examination.

Text furnished: Memorandum 565, Heating and Ventilating II (Fundamentals of Heating).

Each of the following multiple-choice exercises has four choices with only ONE best answer. Select the choice that you believe is best. Check your answers with the solutions provided in this subcourse packet.

When you are satisfied with your understanding of the subject matter, complete the examination and forward the examination answer card to the USAES for grading. The grade you receive on the examination is your grade for the subcourse.

LESSON 1

PRINCIPLES OF HEATING

CREDIT HOURS	2
TEXT ASSIGNMENT	Memorandum 565, chapter 1.
LESSON OBJECTIVE	To teach you the theory, measurement, and use of heat transfer in producing combustion efficiency.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. What part of the heating system of the 14th century is used in modern times?

a. furnace
b. chimney
c. boiler
d. burner

2. The type of heat with which the heating specialist deals is produced by

a. friction
b. chemical action
c. electrical resistance
d. burning of fuels

3. Although heat and temperature have a direct relationship, the distinction between them can be indicated by

a. a burning cigarette and a steam radiator
b. a burning match and a burning newspaper
c. a burning tree and a burning branch
d. a burning coal fire and a burning wood fire

4. The measurement of heat intensity in Fahrenheit or Celsius degrees indicates

a. caloric dissipation
b. caloric intensity
c. temperature
d. thermodynamics

5. The range of the Fahrenheit thermometer between the freezing point and the boiling point is

a. 100°
b. 150°
c. 170°
d. 180°

6. A Celsius temperature of 70° equals a Fahrenheit temperature of

a. 15.8°
b. 21.1°
c. 158°
d. 360°

7. How many Btu's are needed to raise 1 pound of pure water from 32° F to 70° F at sea level?

a. 19
b. 38
c. 40
d. 76

8. The heat that can be measured by a thermometer and sensed or felt is referred to as

a. sensible
b. specific
c. latent
d. total

9. Which of the following indicates absolute zero?

a. 0° F
b. 0° C
c. –260° F
d. –460° F

10. The transfer of heat through space is

a. convection
b. conduction
c. radiation
d. combustion

11. Which of the following differences in temperature will cause the fastest heat flow?

a. room + 90°, outside + 32°
b. room + 80°, outside + 90°
c. room + 70°, outside + 60°
d. room – 30°, outside – 40°

12. The name given to the point at which a substance ignites is

a. kindling
b. pressure
c. static
d. vaporizing

13. Incomplete combustion is usually caused by

a. increased carbon dioxide
b. too much oxygen
c. insufficient carbon monoxide
d. lack of oxygen

14. Carbon monoxide (CO) and carbon dioxide are gases given off during the combustion process. The percentage of these gases depends upon the

a. type of coal and amount of smoke
b. retention of heat and increase of air
c. caloric dissipation and density of flue gas
d. amount of air (oxygen) mixed with the fuel

15. Which of the following would you use to measure CO_2 in flue gas?

a. a smoke comparator
b. a thermometer
c. an orsat
d. furnace peephole

16. The greatest heat loss in a heating unit occurs in the

a. grates
b. peephole
c. chimney
d. radiation

17. If 24 cubic feet of oxygen unite with the fuel, how many cubic feet of nitrogen will enter the combustion chamber?

a. 24
b. 48
c. 75
d. 96

18. The temperature of the flue gas in the stack s 550° F. The flue gas contains 12% carbon dioxide (CO_2). What is the percent of heat loss when burning semibituminous coal?

a. 10.6
b. 11.8
c. 17.00
d. 18.00

19. The flue gas in the stack is 550° F and the fuel gas contains 10% CO_2. You lower the stack temperature to 350° F and raise the CO_2 to 14%. How many pounds of coal per ton would this save? (A ton is equal to 2240 pounds)

a. 150
b. 226
c. 250
d. 300

20. What percent of heat loss is caused by smoke?

a. 2 to 3

b. 5 to 8

c. 15 to 12

d. 25 to 50

LESSON 2

FUEL AND FUEL SYSTEMS

CREDIT HOURS 2
TEXT ASSIGNMENT .... Memorandum 565, chapter 2.
LESSON OBJECTIVE .... To teach you the characteristics, handling, storage, and use of solid, liquid, and gaseous heating fuels.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. What type of coal is referred to as stone coal?

a. lignite
c. bituminous
b. subbituminous
d. anthracite

2. What type of coal is commonly referred to as soft coal?

a. lignite
c. bituminous
b. anthracite
d. subbituminous

3. Chemically, subbituminous coal is distinguished from bituminous by its

a. sulphur content
b. moisture content
c. fixed carbon
d. hydrogen ratio

4. If there are 362,500 Btu's in 25 pounds of dry bituminous coal, how many Btu's are there in 25 pounds of dry subbituminous?

a. 36,250
c. 350,000
b. 337,500
d. 350,500

5. To obtain samples for inspection from a car of coal, you would expose the coal to a minimum depth of how many feet?

a. 2
c. 4
b. 3
d. 6

6. The time to take a sample of coal is

a. during loading or unloading
b. when it is burning
c. when it is in storage
d. while it is in transit

7. A gross coal sample should be a minimum of how many pounds?

a. 400
c. 800
b. 600
d. 1000

8. Your post has received 1500 tons of coal. What is the minimum number of gross samples that you should take?

a. 1
c. 3
b. 2
d. 5

9. The improper storage of coal can cause

a. loss in weight

b. warping of furnace grates

c. spontaneous combustion

d. regrading of stockpiles

10. Storage of bituminous, run-of-mine coal should be limited to a maximum height of how many feet?

a. 13

b. 20

c. 30

d. 35

11. What is the general size in feet of coal stockpiles?

a. 300 x 56

b. 300 x 75

c. 400 x 56

d. 400 x 75

12. You must move the stacker so that you can continue to stack coal in the same pile. What is the maximum number of feet that you could move the stacker?

a. 6

b. 8

c. 10

d. 12

13. You find that a storage pile of coal has developed a hotspot because of spontaneous combustion. What action do you take?

a. flood hotspot with water

b. smother with additional coal

c. remove hotspot with hand shovels

d. remove hotspot with power shovel

14. Which of the following temperatures in a coal stockpile would indicate the presence of a hotspot?

a. 110° F

b. 115° F

c. 120° F

d. 160° F

15. You are unloading fuel oil from a fuel truck. You ground the truck and the oil tank. You do this in order to

a. reduce fuel vapors

b. prevent spark caused by static electricity

c. keep the oil truck in place

d. speed the unloading

16. An oil storage tank should be large enough to hold a supply of oil sufficient for at least

a. 3 days

b. 4 days

c. a week

d. a month

17. You must install a fuel oil storage tank on your post for a heating plant that has been burning 500 gallons per day. What is the minimum number of gallons that the storage tank should hold?

a. 1500

b. 2000

c. 3500

d. 4000

18. You are installing an 80-foot gas line along the ceiling of a building. What is the fewest number of hangers that you could use to hold this pipe?

a. 8

b. 10

c. 12

d. 14

19. How many inches lower should a 200-foot gas pipe line be at one end than at the other?

a. 2

b. 4

c. 6

d. 7

20. Which of the following would you use to check for a gas leak?

a. flashlight

b. lighted candle

c. gas meter

d. soapy water

LESSON 3

HEATING UNIT INSTALLATION

CREDIT HOURS 2

TEXT ASSIGNMENT .... Memorandum 565, chapter 3.

LESSON OBJECTIVE .... To teach you the types of coal, oil, and gas, space heaters, and their installation, operation, and maintenance.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. What percent of the heat from a burning fireplace is lost in the gases and smoke which go up the chimney?

a. 50 to 70
c. 70 to 80
b. 60 to 70
d. 85 to 90

2. An efficient, modern space heater utilizes what percent of the heat from its fuel?

a. 50
c. 75
b. 65
d. 85

3. Another name for a cannon stove is

a. magazine
c. round
b. potbelly
d. top-lift

4. The type of space heater that is lined with firebrick and special fluebrick is the

a. gas-fired
c. magazine
b. oil-fired
d. cannon

5. The magazine stove uses a barometric damper in its smoke pipe in order to

a. maintain a constant draft

b. vary draft to meet temperature changes

c. vary draft to meet changes in wind velocity

d. increase the flow of fuel

6. Which of the following would you place under a space heater that you were installing on a wood floor?

a. sheet metal

b. waterproof canvas

c. rubber mat

d. plywood

7. Which of the following would you install in a coal-fired space heater in order to increase the updraft?

a. wire-mesh hood

b. smokepipe damper

c. updraft blowers

d. downdraft hood

8. Which of the following parts of a cannon stove serve as the principal means of heat radiation?

a. draw grate, round grate, baffle

b. barrel, top neck, top collar

c. cover, top neck, barrel

d. firepot, yoke, bottom

9. Which of the following causes clinkers to form in a coal-fired space heater?

a. chimney soot

b. shaking the grates

c. too much draft

d. too little draft

10. Which of the following is a reason for using copper tubing when installing an oil-fired space heater?

a. eliminates reaming of cut ends

b. is not easily bent

c. high resistance to corrosion

d. requires more threading than iron piping

11. All heating equipment should have a properly constructed chimney of approved size. What is the minimum height in feet that you would make the chimney?

a. 25

b. 30

c. 35

d. 40

12. You are installing a 5-foot horizontal smokepipe from the space heater to the chimney. How many inches of upward pitch do you give this smokepipe?

a. 3

b. 5

c. 6

d. 8

13. You are installing an oil-fired space heater in a building that has the peak of the roof 30 feet from the ground. How many feet should the top of the chimney be above the ground?

a. 20

b. 25

c. 30

d. 33

14. You find that the grates in a coal-fired space heater are badly warped. These grates should be

a. inverted

b. repaired

c. cleaned

d. replaced

15. The burner goes out in your oil-fired space heater. The probable cause is

a. low oil supply

b. stuck needle valve

c. dirty float valve

d. slag in heat exchanger

16. An oil-fired space heater shows high fuel consumption. Which of the following is a probable cause?

a. improper fuel

b. dirt in oil supply line

c. clogged oil strainer

d. dirty float valve

17. How many gallons of water are produced by burning 1000 feet of natural gas?

a. 12

b. 25

c. 50

d. 75

13. The gas pipe used to convey natural or manufactured gas to the space heater is usually made of

a. steel

b. black iron

c. copper

d. lead

19. The purpose of the draft diverter in a gas-fired space heater is to

a. increase downdraft

b. divert flue gas from chimney

c. prevent excessive updraft or downdraft

d. divert heater room air away from flue pipe

20. Insufficient amounts of primary air cause the flame to burn

a. white

b. blue

c. yellow

d. red

LESSON 4

COAL-FIRED FURNACES AND STOKERS

CREDIT HOURS 3

TEXT ASSIGNMENT .... Memorandum 565, chapter 4.

LESSON OBJECTIVE .... To teach you the construction, installation, operation, and maintenance of coal-fired furnaces and automatic stokers.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. What type of warm-air furnace is generally used for gravity heating in small buildings?

a. cast steel
c. wrought iron
b. sheet steel
d. cast iron

2. You have installed a water pan in a warm-air furnace. This will

a. remove moisture from the air
b. lower the water temperature
c. raise circumambient air temperature
d. add moisture to the air

3. Which of the following is the main part of the steel furnace?

a. combustion chamber
b. heat outlet
c. humidifier
d. radiator

4. The purpose for installing filters in warm-air furnaces is to

a. clean the circulating air
b. filter out mechanical noise
c. preheat the cold air
d. decrease air temperature

5. Most steel furnaces are lined with firebrick to prevent the flames from burning through the thin metal during operation. What is this installation called?

a. fire plate
c. damper
b. refractory
d. humidifier

6. You are in charge of a few temporary firemen who will be firing warm-air furnaces burning anthracite coal. What method of firing do you teach them?

a. spreading
b. back-to-front
c. front-to-back
d. center-to-cone

7. You should replace the air-filters in a warm-air furnace at least

a. monthly c. yearly

b. quarterly d. twice a year

8. Which of these stokers creates three zones of fire in the coal bed?

a. spreader c. underfeed

b. chain grate d. overfeed

9. The air openings that are in the retort of an underfeed stoker are referred to as

a. venturis c. air ports

b. air slots d. tuyeres

10. What is the capacity range of hoppers in pounds of coal?

a. 200 to 1000

b. 300 to 1500

c. 375 to 2000

d. 400 to 2500

11. A boiler operates very efficiently at 135 pounds of coal per hour. What type stoker would you use with this boiler?

a. screw-feed

b. underfeed spreader

c. traveling-grate

d. overfeed

12. What largely determines the type of stoker to be used in your heating plant?

a. fuel used

b. number of "deadplates"

c. number of tuyeres

d. size of retort

13. You wish to install a stoker that will handle coal ranging in size from dust to one inch. Which of the following stokers would you select?

a. underfeed c. screw-feed

b. spreader d. traveling-grate

14. Why is there a large number of small holes in the grates used with a spreader stoker?

a. to eliminate fine coal particles

b. to maintain heavy fuel bed

c. to allow even distribution of air

d. to extract coal not burned in suspension

15. You are using a stoker that distributes the coal over the entire grate by means of a nozzle. What type stoker are you using?

a. mechanical spreader

b. traveling-grate

c. overfeed

d. pneumatic spreader

16. A red, smoky fire fed by an automatic stoker would be an indication of

a. insufficient fuel

b. a normal fire

c. too much air or fuel bed too deep

d. insufficient air or too much fuel

17. Proper combustion of coal in the firebox of a furnace or boiler depends upon the size, type, and condition of the

a. windbox c. chimney

b. hopper d. grate

18. A boiler requires a chimney having a cross-sectional area of 48 inches at sea level. How many square inches would the cross-sectional requirement be for this chimney at 5000 feet above sea level?

a. 48

b. 57.6

c. 96.4

d. 100

19. What is the minimum number of cubic feet of air required for complete combustion of 100 pounds of coal?

a. 1000

b. 5000

c. 10,000

d. 15,000

20. What is the minimum height in feet for a chimney?

a. 15

b. 20

c. 25

d. 30

LESSON 5

OIL AND GAS BURNERS AND CONTROLS

CREDIT HOURS	2
TEXT ASSIGNMENT	Memorandum 565, chapters 5 and 6.
LESSON OBJECTIVE	To teach you the equipment, operation, and maintenance of various types of oil and gas burners and their operational controls.

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. Gun-type domestic oil burners atomize the oil by oil pressure or by low-pressure air. At how many pounds per square inch (psi) is the oil pressure normally used?

a. 25
b. 50
c. 75
d. 100

2. The type nozzle that you select for a gun-type high-pressure burner furnace depends upon the

a. speed of compressors
b. number of electrodes
c. size of furnace or boiler
d. number of insulators

3. You are installing an oil burner that has a single-stage fuel unit. The fuel tank for it should be

a. underground
b. outside boiler room
c. alongside burner
d. elevated

4. The refractory in vertical rotary burners

a. vaporizes the oil
b. atomizes the oil
c. protects driving parts
d. controls the flames

5. The total flue area of an oil burner chimney is 100 square inches. What is the maximum number of square inches of this flue area that you could close off by means of the flue dampers?

a. 80
b. 85
c. 90
d. 95

6. Which of the following would you use to clean the nozzle in a domestic oil burner?

a. safety solvent
b. soapy water
c. wire
d. carbon mixture

7. What shapes the oil spray pattern in an air-turbine commercial oil burner?

a. fan housing

b. atomizer

c. air inlet

d. air butterfly valve

8. You are installing a conversion oil burner in a steam boiler. There are 15 radiators with 100 square feet of EDR (equivalent direct radiation) each. What is the size of the nozzle, in gallons per hour, that you will need?

a. 5.0 c. 10.0

b. 7.5 d. 15.0

9. For proper burner control maintenance, the contact points of the individual control units should be cleaned and all electrical contacts tightened. How often would you do this?

a. once each year c. monthly

b. semi-annually d. weekly

10. The pressure reading on a manometer is expressed in inches of

a. oil c. water or mercury

b. gas d. air

11. Which of the following gas burners is equipped with an electric motor?

a. upshot c. combination

b. inshot d. premix

12. Which of the following burners would you use for firing both coal and gas?

a. premix c. upshot

b. inshot d. combination

13. A gas burner has 100 percent cutoff safety pilots. What type of gas does it use?

a. propane

b. natural gas

c. liquified petroleum gas

d. butane

14. A yellow flame in a gas burner indicates

a. absence of carbon

b. poor air-fuel mixture

c. correct air-fuel mixture

d. complete combustion

15. What happens to the gas solenoid valve when its supply of electric current fails?

a. it opens

b. it closes

c. the valve disc is unseated

d. the coil is energized

16. Which of the following gas valves has a device which allows manual operation of the valve during failure of electric current?

a. recycling solenoid

b. diaphragm

c. thermocouple

d. thermopile

17. Which of the following valves has as its main feature the absence of valve noise when it is opening or closing?

a. diaphragm

b. pilot

c. gas metering

d. recycling solenoid

18. Thermocouples and thermopiles are used to operate

a. thermostats c. safety devices

b. venturi d. transformers

19. Which of the following is the cause of most inoperative gas burners?

a. thermostat

b. pilot light

c. transformer

d. pressure regulator

20. The color of the pilot flame in a gas burner should be

a. red

b. yellow

c. blue, with yellow tip

d. blue

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 565-1 . . . . Heating and Ventilating II (Fundamentals of Heating).

LESSON 1 . . . . Principles of Heating

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 565.

1. *b* (pars 3 and 4, col. 1, p. 1)
2. *d* (par 1-1)
3. *a* (par 2-2)
4. *c* (par 2-2)
5. *d* (par 2-3)
6. *c* (par 2-4)
7. *b* (par 2-5)
8. *a* (par 2-4)
9. *d* (par 2-9)
10. *c* (par 2-14)
11. *a* (par 2-10)
12. *a* (par 3-3)
13. *d* (par 4-6)
14. *d* (par 4-4)
15. *c* (par 6-1)
16. *c* (par 7-1)
17. *d* (par 7-2)
18. *d* (par 8-2)
19. *b* (par 8-3)
20. *a* (par 7-1)

For further explanation, see Discussion.

All concerned will be careful that neither this solution nor information concerning the same comes into the possession of students or prospective students who have not completed the work to which it pertains.

DISCUSSION

Exercise:

1. In the 13th and 14th centuries hollow stone **chimneys (b)** began to be used. In colonial United States, chimneys projected through the roof or combined with the gable end walls. This general trend is often followed in architecture today.

2. The particular form of generated heat with which the heating specialist deals is produced by **burning** common types **of fuel (d)** such as oil, coal, and gas.

3. Although heat and temperature have a direct relationship, there is also a distinction between them. For example **a burning match** develops a much higher temperature than **a steam radiator (a)** but the match does not give off enough heat to warm the room.

4. **Temperature (c)** is the measurement of heat intensity in degrees Fahrenheit or Celsius.

5. The range of the Fahrenheit thermometer between the freezing point and the boiling point is **180° (d)** (32° to 212° = 180°) as shown figure 1.

6. To change a Celsius reading to Fahrenheit, multiply the Celsius reading by 9/5 and add 32°.

70° × 9/5 = 126° + 32° = 158° (c).

7. One Btu is needed to change the temperature of 1 pound of water by 1° F at sea level. To raise the water 38° (70° – 32°) would, therefore, require **38 (b)** Btu's.

8. The heat that can be measured by a thermometer and sensed or felt is referred to as **sensible (a)** heat.

9. Scientists have arbitrarily determined that when the temperature of a substance has been reduced to **–460° F (d)** practically all the heat has been removed and the molecules cease to have motion. This temperature is known as absolute zero.

10. **Radiation (c)** is the transfer of heat through space. In this manner, the earth receives its heat from the sun.

11. There must be a temperature difference before heat will flow. The greater the difference in temperature, the faster the heat flow. Choice (a) with a difference of 58° would cause the fastest heat flow.

12. The **kindling (a)** point of a substance is the temperature to which a substance must be heated for it to ignite.

13. Incomplete combustion is usually caused by the **lack of oxygen (d)** during the burning process or by the improper mixing of oxygen with combustible fuel.

14. Carbon monoxide (CO) and carbon dioxide (CO_2) are the two gases of importance to firemen. The percentage of these given off during the combustion process depends on the **amount of air (oxygen) mixed with the fuel (d).**

15. The most reliable measurement of the percentage of carbon dioxide in flue gas is made by using a gas analyser, or **orsat (c)**. A typical orsat is shown in figure 3.

16. Heat loss occurs through the grates and through conduction, convection, and radiation, but the heat loss up the **chimney (c)** is by far the greatest thief.

17. For each cubic foot of oxygen that unites with the fuel, 4 cubic feet of nitrogen enter the combination chamber, (24 cu ft oxygen × 4 = **96 (d)** cu ft nitrogen.)

18. The use of the heat loss scale in figure 4 shows that the heat loss would be **18 (d)** percent.

19. Use figure 4

Heat loss at 550° F and 10% CO_2 = 20.7 percent
Heat loss at 350° F and 14% CO_2 = 10.6 percent
a saving of 10.1 percent

2240 pounds (ton) × 10.1 = **226 (b)** pounds saved.

20. Smoke, contrary to public conception, forms only a small percentage of the total heat loss; not over **2 to 3 (a)** percent.

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 565-1 . . . . Heating and Ventilating II (Fundamentals of Heating).

LESSON 2 . . . . Fuels and Fuel Systems.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 565.

1. *d* (par 10-3)
2. *c* (par 10-4)
3. *b* (par 10-5)
4. *b* (par 10-5)
5. *a* (par 10-9)
6. *a* (par 10-16)
7. *d* (par 10-17)
8. *b* (par 10-17)
9. *c* (par 10-22)
10. *a* (par 10-24)
11. *a* (par 10-26)
12. *a* (par 10-27)
13. *d* (par 10-33)
14. *d* (par 10-31)
15. *b* (par 11-8)
16. *c* (par 11-9)
17. *c* (par 11-9)
18. *a* (par 12-8)
19. *b* (par 12-9)
20. *d* (par 12-10)

For further explanation, see Discussion.

DISCUSSION

Exercise:

1. **Anthracite (d)** is the hardest grade of coal obtained. It is very dense and stonelike in structure and has been referred to as stone coal.

2. **Bituminous** (c) coal is commonly referred to as soft coal. It has a wide variety of physical and chemical properties.

3. Chemically, subbituminous coal is distinguished from bituminous by its high **moisture content** (b), which ranges from 20 to 30 percent.

4. The average Btu content of subbituminous coal is about 1000 less per pound dry than dry bituminous.

25 pounds dry bituminous = 362,500 Btu (given)
25 pounds dry subbituminous × 1000 = 25,000 Btu less than dry bituminous
337,500 (b) Btu's in 25 pounds dry subbituminous.

5. The entire top of the carload is examined closely. It is inspected at nine or more points in three diagonal lines across the top of the car. Dig into the coal and expose it to a minimum depth of 2 (a) feet.

6. The time to take the sample of coal is while the coal itself is in motion, that is, **during the loading or unloading (a).**

7. A gross coal sample, totaling not less than **1000 (d)** pounds of coal, should be gathered in proportionate amounts from the total number of cars to be examined.

8. You must take 2 (b) samples. A gross sample must not be representative of more than 1000 tons; and so another gross sample must be taken to represent the additional 500 tons.

9. The improper storage of coal can cause **spontaneous combustion** (c). A typical storage layout is shown in figure 12.

10. Storage of bituminous, run-of-mine coal should be limited to a maximum height of 13 (a) feet unless higher stockpiling is approved by the Army command concerned.

11. Coal is generally stored in stockpiles that are **300 feet long and 56 feet wide (a).**

12. When the maximum height of the stacker is reached, it should be moved a sufficient distance to discharge the coal on the side and near the top of the stockpile. This distance should not exceed 6 (a) feet.

13. Hot or burning coal should be **removed** from a stockpile preferably with clamshell cranes, **power shovels** (d) or all metal conveyers. Removing the coal with hand shovels is dangerous.

14. If the temperature rises to about **160° F** (d) within a week, there is danger of spontaneous ignition, and you should remove the hot spot immediately.

15. **A spark caused by static electricity (b)** can cause an explosion that can result in death or injury to you or your fellow workers. Grounding minimizes this danger.

16. The storage tank should be large enough to hold **1 week's (c)** supply of oil, estimated at the maximum rate of consumption.

17. The storage tanks should be large enough to hold at least 1 week's supply of oil, estimated at the maximum rate of consumption.

(500 gals × 7 days = **3500 gals (c)**).

18. Gas pipes should be fastened and supported with hooks, straps, bands or hangers at intervals of not more than 8 to 10 feet.

(80 ÷ 10 = 8 (a)).

19. Gas lines from the main supply to the burner should be graded at least 1 inch for every 50 feet of pipe (200 ÷ 50 = 4" (b)) to prevent water from collecting in the lines.

20. A solution of **soapy water (d)** is applied with a brush at each joint when checking for gas leaks. A soap bubble will form at the joint if a gas leak exists.

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 565-1 . . . . Heating and Ventilating II (Fundamentals of Heating).

LESSON 3 . . . . Heating Unit Installation.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 565.

1.	*d*	(par 2, page 27, col 1)
2.	*c*	(par 13-1)
3.	*b*	(par 13-5)
4.	*c*	(par 13-10)
5.	*a*	(par 13-12)
6.	*a*	(par 13-15)
7.	*d*	(par 13-16)
8.	*b*	(par 13-8)
9.	*c*	(par 13-22)
10.	*c*	(par 13-37)
11.	*a*	(par 13-42)
12.	*b*	(par 13-44)
13.	*d*	(par 13-42)
14.	*d*	(par 13-21)
15.	*a*	(par 13-52)
16.	*a*	(par 13-52)
17.	*a*	(par 13-61)
18.	*b*	(par 13-59)
19.	*c*	(par 13-63)
20.	*c*	(par 13-65)

For further explanation, see Discussion.

DISCUSSION

Exercise:

1. From **85 to 90 (d)** percent of the heat from a fireplace is lost in the gases and smoke which go up the chimney. The design of fireplaces is for style rather than for thermal efficiency.

2. An efficient, modern space heater utilizes about 75 (c) percent of the heat of the fuel burned in it.

3. The cannon stove is the space heater that is commonly known as the **potbelly (b) stove.** It is illustrated in figure 22.

4. The **magazine** (c) stove is made of sheet steel, and lined with firebrack and special fluebrick to prevent damage to the sheet steel by the heat.

5. The barometric damper is a weighted damper that **maintains a constant draft (a)** regardless of wind and temperature. It helps prevent overheating and conserves fuel.

6. Some type of insulation must be placed between the heater and a floor made of combustible materials. In some cases, this insulation is a piece of **sheet metal (a)** and in other cases it is a bed of sand in a metal frame.

7. A specially designed **downdraft hood (d)** can be installed when it is necessary to increase updraft.

8. The top neck and top collar, to which the heater flue is attached, are supported by the barrel. **The barrel, the top neck, and the top collar (b)** serve as the principal means of heat radiation.

9. **Too much draft (c)** will overheat the stove, causing ashes to fuse into clinkers, and too little draft can cause the fire to go out.

10. Copper tubing is often used in an oil supply system for oil-fired space heaters because of its **high resistance to corrosion (c)** and ease of installation.

11. A good chimney should be at least **25 (a)** feet high, of approved size, and with no sharp turns or abrupt offsets.

12. Install the smokestack with an upward pitch of not less than one inch per running foot of length (1″ × 5 = 5″ **(b)**).

13. The chimney should extend at least 3 feet above the highest point of the roof or any other structure or obstruction within 30 feet of it. (30′ + 3′ = **33′ (d)**).

14. If air to the grates is restricted by ashes, the grates become so hot that they warp. These "burned out" grates must be **replaced (d).**

15. Of the choices listed in the exercise, only **low oil supply (a)** is given as a probable cause in the third section of chart 1.

16. **Improper fuel (a)** is a probable cause of the high fuel consumption, as shown in the fifth section of chart I.

17. Approximately 12 (a) gallons of water are produced by burning 1000 cubic feet of natural gas.

18. The gas line used to convey natural or manufactured gas to the space heater is usually black iron (b) pipe.

19. The purpose of the draft diverter is to prevent the chimney from producing an excessive updraft or downdraft (c) condition.

20. Insufficient amounts of primary air cause the flame to burn yellow (c) and result in sooting of the unit.

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 565-1 . . . . Heating and Ventilating II (Fundamentals of Heating).

LESSON 4 . . . . Coal-fired Furnaces and Stokers.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 565.

1. *d* (par 14-2)
2. *d* (par 14-12)
3. *a* (par 14-17)
4. *a* (par 14-26)
5. *b* (par 14-21)
6. *b* (par 14-28)
7. *c* (par 14-48)
8. *c* (par 15-4)
9. *d* (par 15-4)
10. *c* (par 15-6)
11. *a* (par 15-5)
12. *a* (par 15-3)
13. *b* (par 15-15)
14. *c* (par 15-16)
15. *d* (par 15-21)
16. *d* (par 15-49)
17. *c* (par 16-3)
18. *b* (par 16-7)
19. *d* (par 16-3)
20. *a* (par 16-7)

For further explanation, see Discussion.

DISCUSSION

Exercise:

1. The **cast iron (d)** furnace is generally used for gravity heating in small buildings, and is an older type than the sheet steel furnace.

2. Water pans (figure 45) are sometimes used as humidifiers to **add moisture to the air (d)**. It is thus possible to be comfortable at lower temperatures.

3. The main part of the steel furnace is the **combustion chamber (a)** around which the air passes as it is heated by the fire on the inside.

4. When a blower is used, one or more filters (figure 52) are installed to **clean the circulating air (a)**.

5. The installation is called the **refractory (b)**. The firebrick also helps absorb and deaden the sound of combustion.

6. For uniformity and simplicity of instruction, and for best results with temporary firemen, the **back-to-front (b)** method is preferable for anthracite firing.

7. You should replace the air filters at least **once a year (c)**. When a filter becomes dirty, it slows the flow of air and does not provide the proper filtering.

8. When firing with an **underfeed stoker (c)**, there are three zones which exist in the fuel bed. They are: fresh or green on the bottom, coking zone in the middle, and the incandescent or burning zone at the top.

9. The openings are usually located at the top or sides of the retort. The air enters through these openings in parts of the stoker called **tuyeres (d)**.

10. Hoppers vary in capacity from **375 to 2000 (c)** pounds.

11. **The screw-feed (a)** stoker is used for small boilers. It is available for coal-burning rates ranging from 100 to 200 pounds per hour.

12. Four basic types of automatic stokers have been developed. Each type of stoker has its own field or use, depending largely on the **fuel used (a)**.

13. **Spreader (b)** coal stokers can handle coal ranging in size from coal dust to about 1¼ inches.

14. The grates that are used have a large number of small holes or openings which **allow even distribution of the air (c)** necessary for maintaining a thin fuel bed.

15. The **pneumatic spreader (d)** stoker is illustrated in figure 60. It distributes the coal over the entire grate by means of the spreader nozzle.

16. A red, smoky fire indicates **insufficient air or too much fuel (d)**. Make your adjustments accordingly.

17. The proper combustion of coal in the firebox of a furnace or boiler depends upon the size, type, and condition of the **chimney (c)** that carries away the flue glasses.

18. Generally, the cross-sectional area of chimneys must be increased **4%** for every 1000 feet of altitude above sea level.

$$\frac{5000}{1000} \times .04 \times 48 + 48 = \mathbf{57.6\ (b)}\ \text{sq in.}$$

19. The minimum number of cubic feet is **15,000 (d)** because every pound of coal requires from 150 to 250 cu ft of air for complete combustion.

20. Chimneys should be extended at least 3 feet above the peak of the roof and should never be less than **15 (a)** feet high, even for small stokers.

CORRESPONDENCE COURSE OF U. S. ARMY ENGINEER SCHOOL

SUBCOURSE 565-1 . . . . Heating and Ventilating II (Fundamentals of Heating).

LESSON 5 . . . . Oil and Gas Burners and Controls.

SOLUTIONS

Each exercise has a weight of 5. All references are to Memorandum 565.

1. *d* (par 17-2)
2. *c* (par 17-14)
3. *d* (par 17-10)
4. *c* (par 17-18)
5. *a* (par 17-21)
6. *a* (par 17-24)
7. *b* (par 18-3
8. *a* (par 20-2)
9. *a* (par 21-8)
10. *c* (par 23-3)
11. *d* (par 24-7)
12. *d* (par 24-8)
13. *c* (par 24-10)
14. *b* (par 25-1)
15. *b* (par 26-5)
16. *a* (par 26-6)
17. *a* (par 26-7)
18. *c* (par 26-11)
19. *b* (par 27-8)
20. *d* (par 27-9)

For further explanation, see Discussion.

DISCUSSION

Exercise:

1. The oil pressure normally used is about **100 (d)** pounds per square inch (psi), but pressure considerably higher than this is sometimes used.

2. The high-pressure gun-type nozzle is rated in gallons per hour (gph) and the nozzle selected depends on the **size of the furnace or boiler (c)**.

3. The single-stage unit is best adapted where an **elevated (d)** tank is used and the oil is fed by gravity to the burner.

4. The burner must be installed so that the **driving parts are protected (c)** from the heat of the flame by a hearth or refractory material at about grate level.

5. Flue dampers must be constructed so that not more than 80 percent of the internal area of the flue can be closed off, and a draft regulator is required. (100 sq in × 80% = **80 (a)** sq in.)

6. It is necessary for you to remove soot and carbon deposits from the nozzle. It is a delicate unit and should be handled with care. Use **safety solvent (a)** to clean the nozzle. Compressed air also can be used.

7. The turbine-driven oil burner is designed so that part of the air is forced through the turbine. The turbine rotates the **atomizer (b)** which shapes the oil pattern.

8. To determine the size of the nozzle for steam boiler operation, figure the amount of radiation for each radiator, add these amounts, and divide the sum by 300.

$$\left(\frac{15 \times 100}{300} = 5 \text{ (a) gph.}\right)$$

9. You should do the checks mentioned in the exercise **once each year (a)**. As a general rule, oil burner controls are quite trouble-free.

10. Although the pressure in the manometer is referred to as inches of **water or mercury (c)**, it may also be expressed in ounces or pounds psi.

11. **Premix (d)** gas burners are equipped with an electric motor and a blower that compress the air and mix it with gas at the same time.

12. **Combination (d)** gas and oil burners are used for the purpose of firing these two different types of fuel, but not, of course, at the same time.

13. The **liquified petroleum gas (c)** burners require 100 percent cutoff safety pilots. The normal gas pressure for these L.P.G. gases is slightly higher than for natural gases.

14. A yellow flame indicates a **poor air-fuel mixture (b)** and that carbon is being formed as the result of incomplete combustion.

15. When there is a current failure, the solenoid valve automatically **closes (b)**, causing the gas pressure in the line to hold the valve disc upon its seat.

16. The design of the **recycling solenoid valve (a)** includes an automatic recycling device which allows the valve to switch to manual operation during current failure.

17. The **diaphragm (a)** valve has as its main feature the absence of valve noise when it is opening or closing.

18. In the heating field, thermocouples and thermopiles are used to produce the electrical current used to operate such units as heating unit gas valves, relays, and other **safety devices (c)**.

19. Either directly or indirectly, the **pilot light (b)** is usually the cause of most inoperative gas burners.

20. The pilot flame should be a **blue (d)** color, without a yellow tip. A yellow flame indicates improper combustion.

EXAMINATION

ARMY CORRESPONDENCE COURSE • ENGINEER SUBCOURSE 565-1

HEATING AND VENTILATING II
(FUNDAMENTALS OF HEATING)

CREDIT HOURS ________________________ 2

TEXT ASSIGNMENT ____________________ Review previous assignments.,

---

EXERCISES

Requirement. Solve the following multiple-choice exercises.

1. One pound of water is at 40° F at sea level. How many Celsius degrees must the water be raised in order that the water will be at the Celsius boiling point?

a. 60
b. 75.5
c. 95.6
d. 140

2. How many Btu are needed to change 1 pound of ice to water?

a. 100
b. 120
c. 130
d. 144

3. How many additional Btu are needed to raise the water in exercise 2 to the boiling point?

a. 150
b. 160
c. 170
d. 180

4. How many additional Btu are needed to change the boiling water in exercise 3 to steam?

a. 800
b. 875
c. 900
d. 970

5. What is total heat?

a. sensible heat plus latent heat
b. super heat less specific heat
c. sensible heat plus specific heat
d. specific heat plus sensible heat

6. If you hold one end of a stove poker in a flame, soon the other end will become too hot to hold. This transfer of heat is called

a. insulation
b. conduction
c. convection
d. radiation

7. The transfer of heat through mediums such as water, air, and steam is called

a. radiation
b. fusion
c. convection
d. conduction

8. How often, at least, would you inspect coal storage piles for evidence of excessive heating or spontaneous combustion?

a. once a week
b. every two weeks
c. monthly
d. quarterly

9. What should be done with coal that has been damaged by heat or fire?

a. discarded

b. aerated and used at once

c. mixed with undamaged coal

d. stored in different area

10. What type of gas must be used as fast as it is produced?

a. liquified petroleum

b. natural

c. manufactured

d. blast-furnace

11. In scheduling refueling for the U. S. Army No. 1 space heater, you would keep in mind that this heater holds how many pounds of coal?

a. 65 c. 85

b. 70 d. 100

12. You must install a coal-fired space heater in a room. Where in the room do you place the heater?

a. any corner

b. 3′ from a wall

c. in the center

d. adjoining entrance door

13. The smokepipe between the space heater and the chimney should have as few bends and joints as possible in order to

a. increase resistance to flow of smoke

b. reduce resistance to flow of smoke

c. increase convection

d. reduce conduction

14. The correct flow of air to vaporizing type oil burners depends primarily on

a. chimney draft

b. grade of oil

c. weight of damper

d. fuel supply tubing

15. The continuous action of hot air rising in the chimney and being replaced by cold air drawn through the space heater is called

a. draft c. combustion

b. conversion d. conduction

16. In troubleshooting an oil-fired space heater, you find that the burner smokes. Which of the following do you consider a probable cause?

a. low oil supply

b. dirty float valve

c. improper fuel

d. needle valve stuck

17. Space heaters using liquified petroleum gas must have 100 percent shutoff thermostatic pilots. Which of the following operates this shutoff?

a. nozzle assembly c. thermopile

b. thermocouple d. venturi

18. When a radiator is added to a cast iron coal furnace, the result is

a. increased heat loss

b. lower combustion temperatures

c. decreased heat transfer

d. better heat transfer

19. You are operating a spreader-type stoker. The flow of fuel stops. How long can the fuel already on the grates keep the fire going?

a. 1 hour c. 15 minutes

b. 30 minutes d. 5 or 6 minutes

20. The pneumatic spreader stoker can be used with boilers having up to how many square feet of heating space?

a. 3000 c. 4500

b. 3500 d. 5000

21. You have a gun-type oil burner in operation, and you hear a buzzing sound in the oil tank. What action do you take to correct this condition?

a. check antihum diaphragm

b. adjust intake port

c. tighten pressure regulating screw cap

d. clean bypass plug

22. Which of the following lists the three indispensable parts of the gun-type, low-pressure burner?

a. separating chamber, oil strainer, muffler

b. pressure adjustment, cutoff valve, sump

c. rotary compressor, sump, nozzle

d. draft tube, thrift meter, oil adjustment

23. In the horizontal rotary oil burner that is driven by an electric motor, the oil is atomized by

a. centripetal force

b. centrifugal force

c. air pressure

d. gravitational pull

24. A furnace has a connecting-duct area of 400 square inches. What size (in gallons per hour) burner nozzle would you use?

a. 1 c. 4

b. 2 d. 5

25. What is the operational gas pressure used in low-pressure gas systems?

a. 1 ounce to 2 psi

b. 2 ounces to 3 psi

c. 3 ounces to 4 psi

d. 4 ounces to 6 psi

26. What is the operational gas pressure, in psi, used in high-pressure gas systems?

a. 1 to 10 c. 2 to 25

b. 2 to 20 d. 3 to 30

27. Which of the following conveys gas to several burner units in a low-pressure system?

a. multiple feeder c. spud

b. thermopile d. manifold

28. Gas burners that are horizontal firing through spuds are called

a. radiant c. upshot

b. Bunsen d. inshot

29. Upshot burners are

a. vertical

b. horizontal

c. easily converted to oil

d. uniform in surface design

30. Which of the following burners would you use to extract the maximum amount of heat from natural gas?

a. combination c. upshot

b. premix d. inshot